Institute of Paper Science and Technology

SLIDE MATERIAL

To The

PAPER PHYSICS

PROJECT ADVISORY COMMITTEE

April 29, 1993

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To The

PAPER PHYSICS

PROJECT ADVISORY COMMITTEE

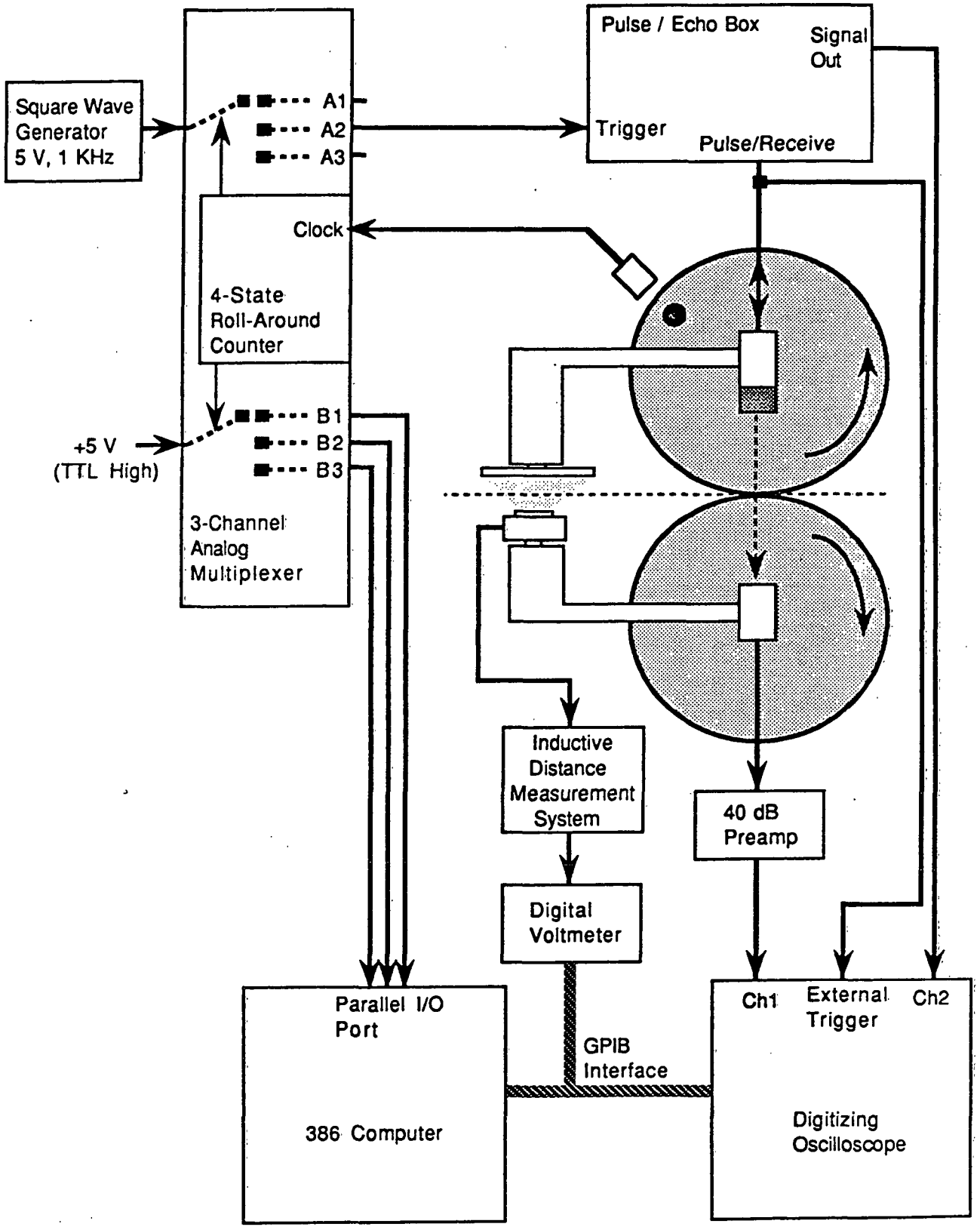
April 29, 1993
Institute of Paper Science and Technology
Atlanta, Georgia

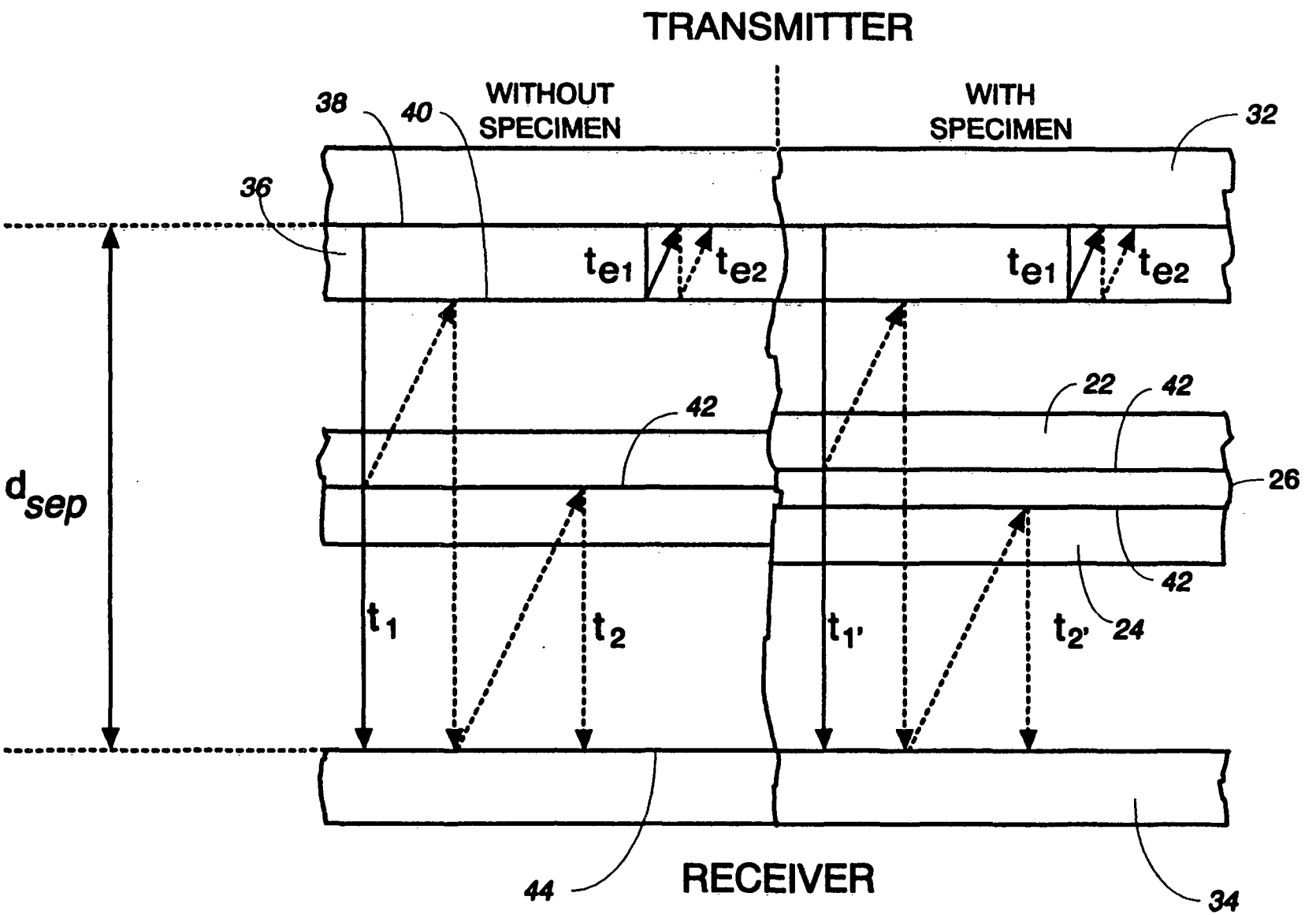
ON-LINE MEASUREMENT OF PAPER PROPERTIES

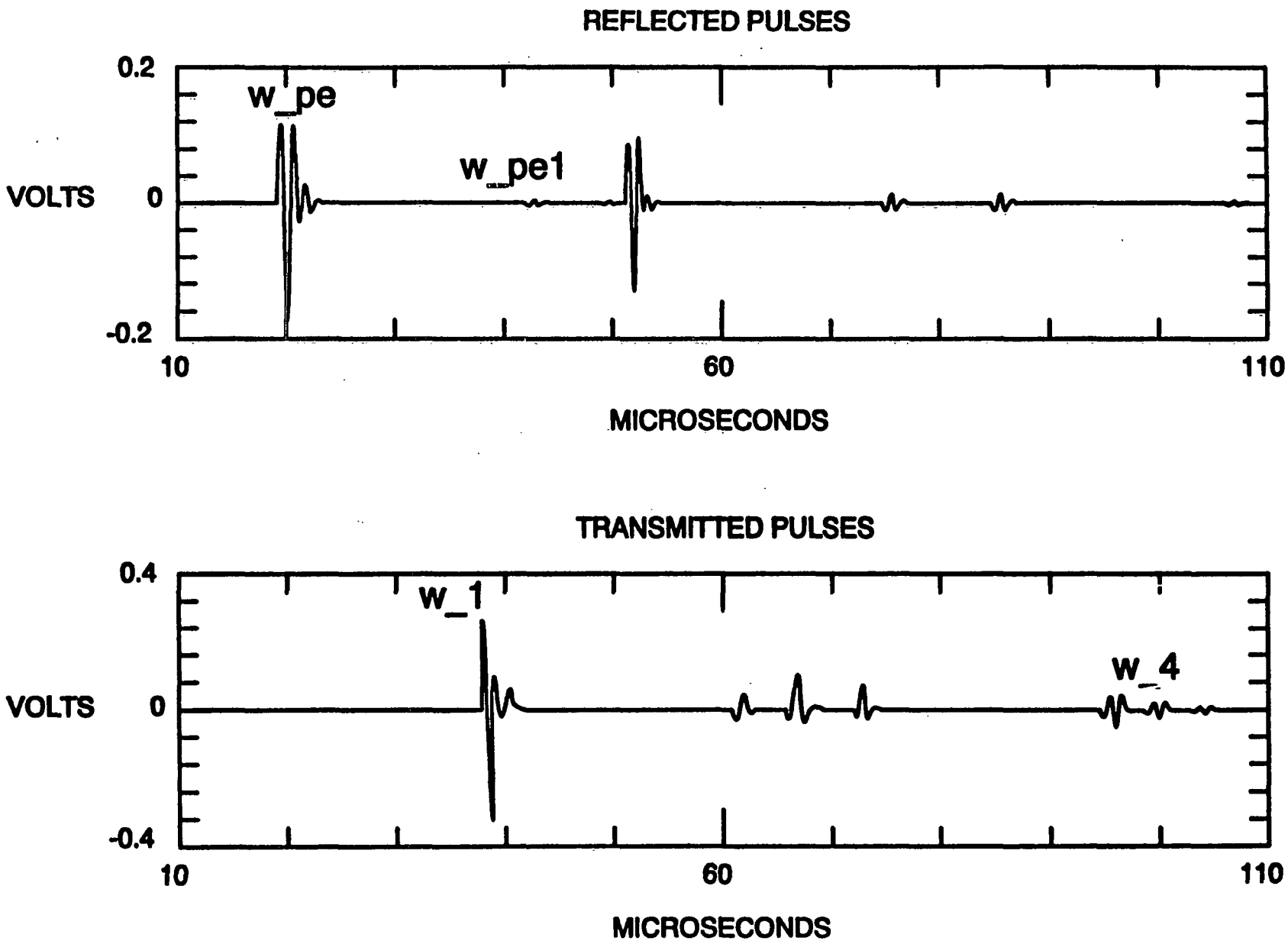
By

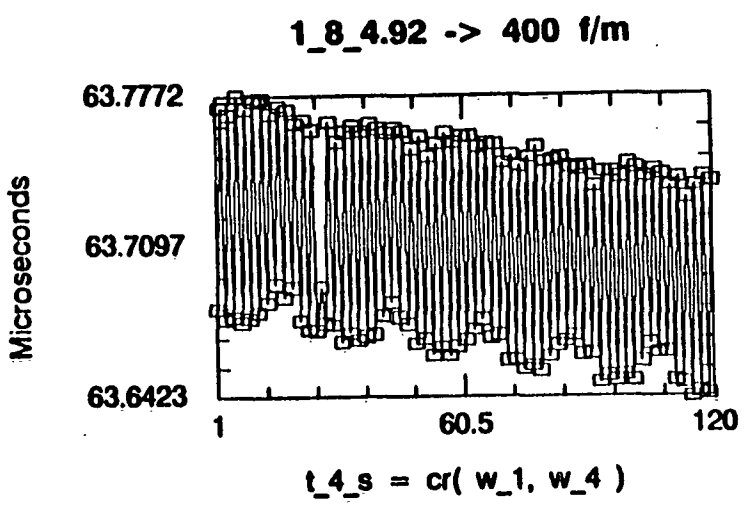
Maclin S. Hall
Associate Professor of Physics

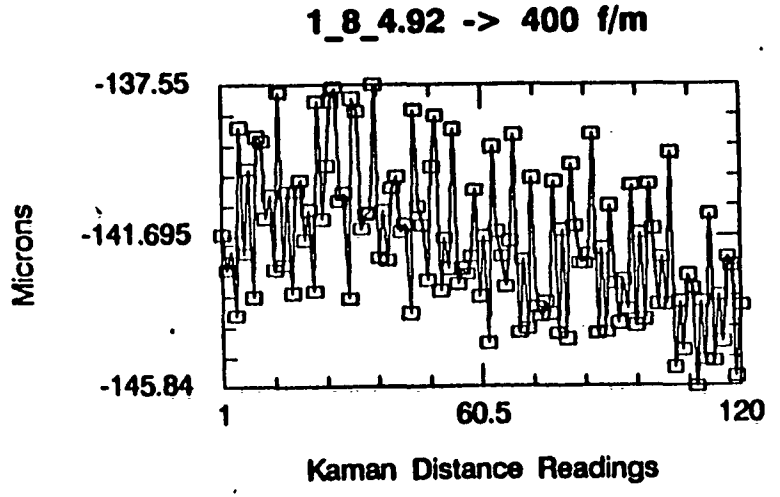
ZD Ultrasonic Averaging Measurement System

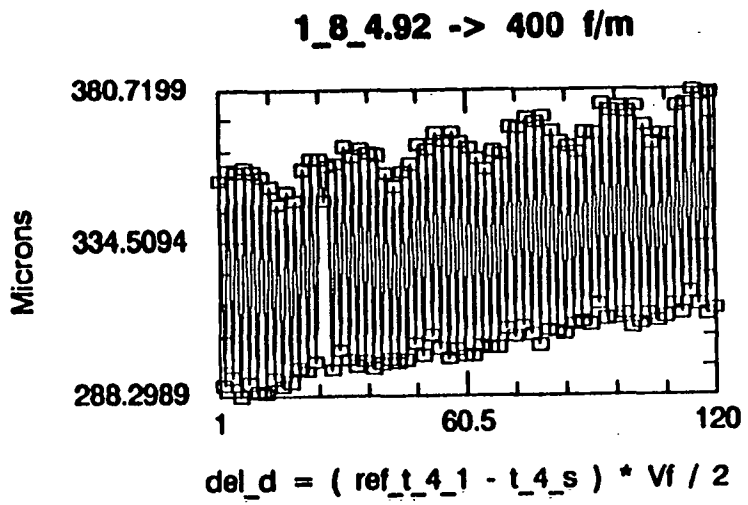


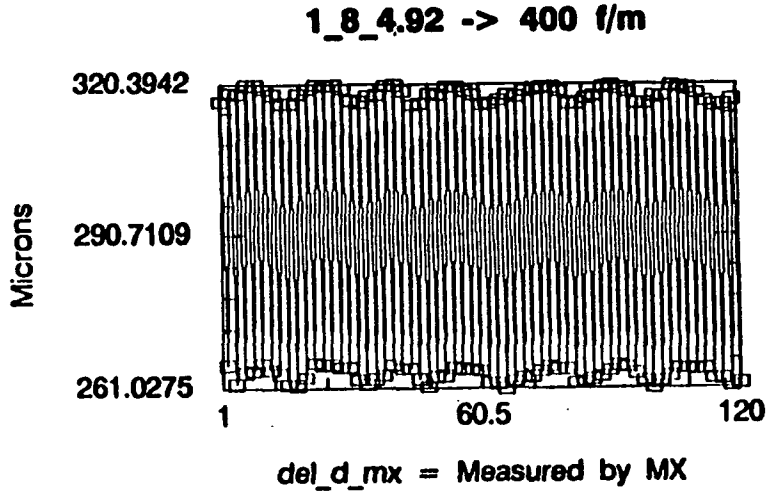

TRANSMITTER
WITHOUT SPECIMEN
WITH SPECIMEN
38
40
32
36
t_{e1}
t_{e2}
t_{e1}
t_{e2}
22
42
42
26
42
d_{sep}
t_1
t_2
$t_{1'}$
$t_{2'}$
24
44
RECEIVER
34


REFLECTED PULSES
0.2
w_pe
w_pe1
VOLTS
0
-0.2
10
60
110
MICROSECONDS
TRANSMITTED PULSES
0.4
w_1
w_4
VOLTS
0
-0.4
10
60
110
MICROSECONDS



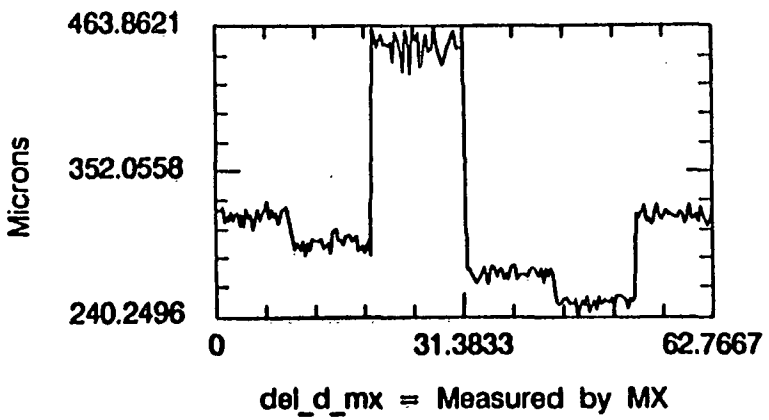






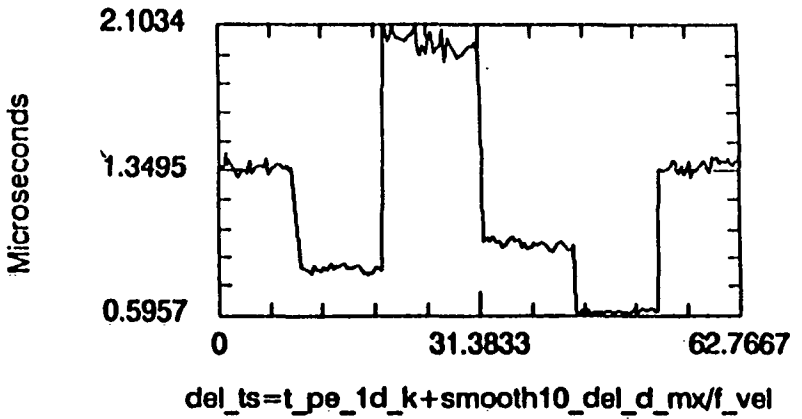
ZD data. Two-section belt of two different 42# liners. Shows temperature effect on FFW caliper versus MX caliper gauge.

2_26_2.92 -> 1 Rev Avg, Multi-Sec Reel



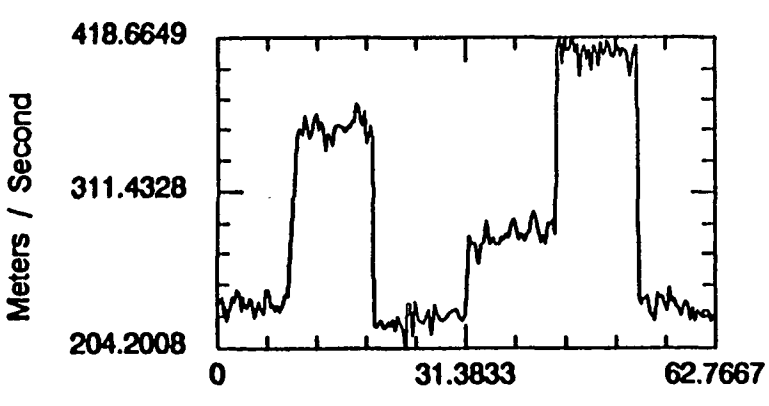
del_d_mx = Measured by MX

2_26_2.92 -> 1 Rev Avg, Multi-Sec Reel



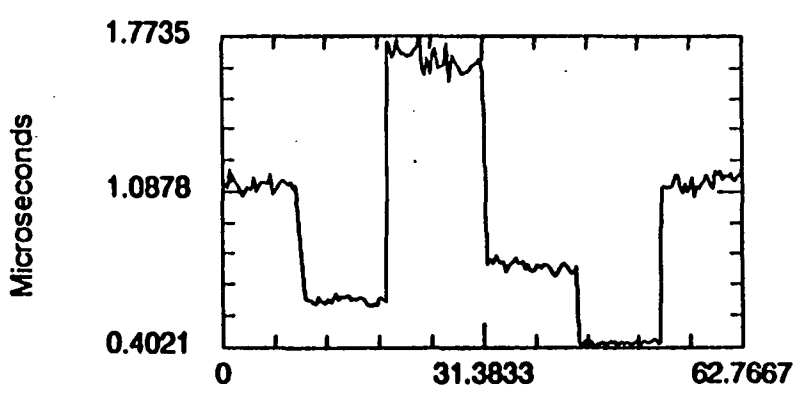
del_ts=t_pe_1d_k+smooth10_del_d_mx/f_vel

2_26_2.92 -> 1 Rev Avg, Multi-Sec Reel



vel_s_mx = smooth_del_d_mx / del_ts

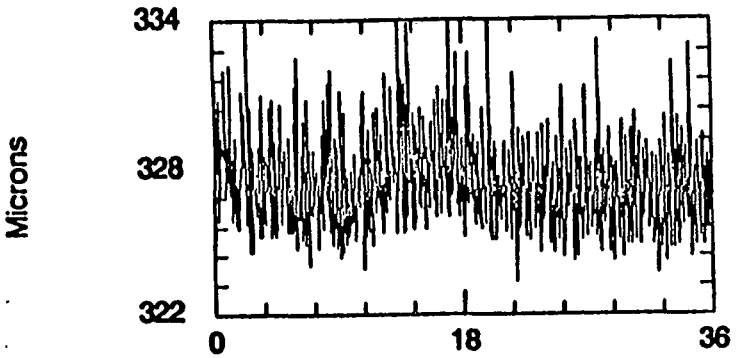
2_26_1.92 -> Free-Run, Multi-Sec Reel



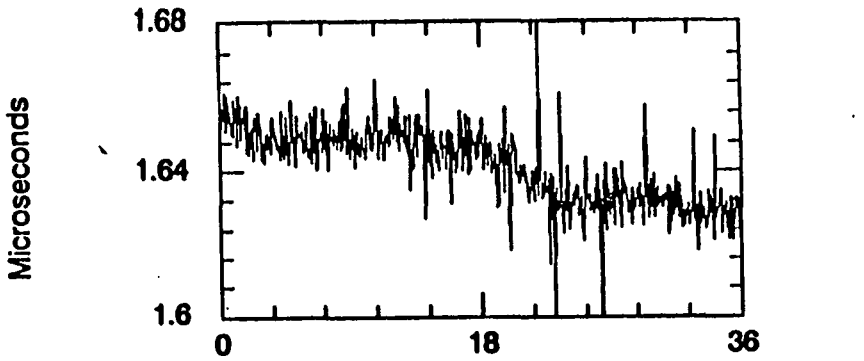
t_pe_1d = cr(w_pe,w_1)-cr(ref_w_pe,ref_w_1)

ZD data. Thickness determined by MX caliper gauge. Six section roll; 42# Liner(A), 42# Liner(B), 69# Liner, 42# Liner(C), 26# Medium, 42# Liner(A).

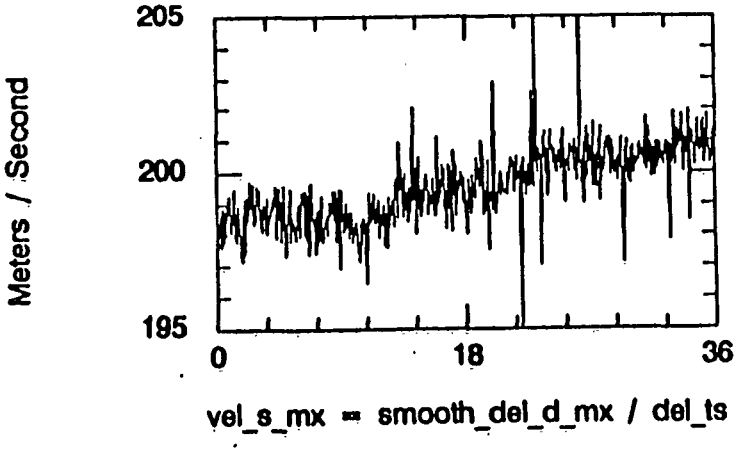
2_28_2.92 -> Foil-Start Avg 50 belt, 2000 f/m



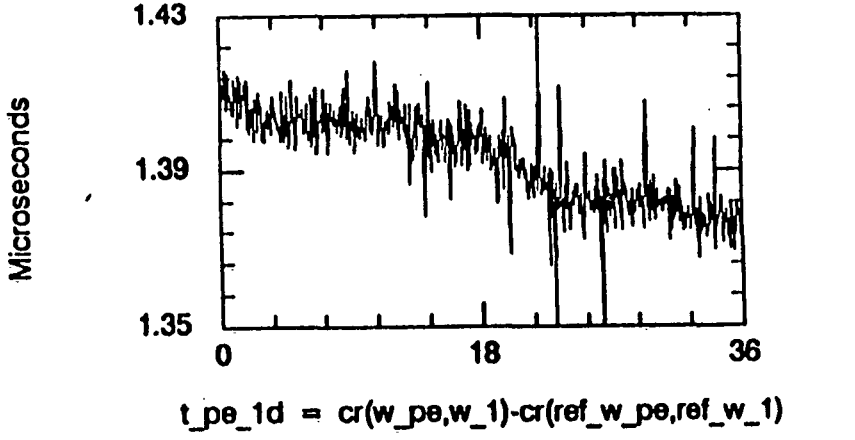
2_28_2.92 -> Foil-Start Avg 50 belt, 2000 f/m



2_28_2.92 -> Foil-Start Avg 50 belt, 2000 f/m

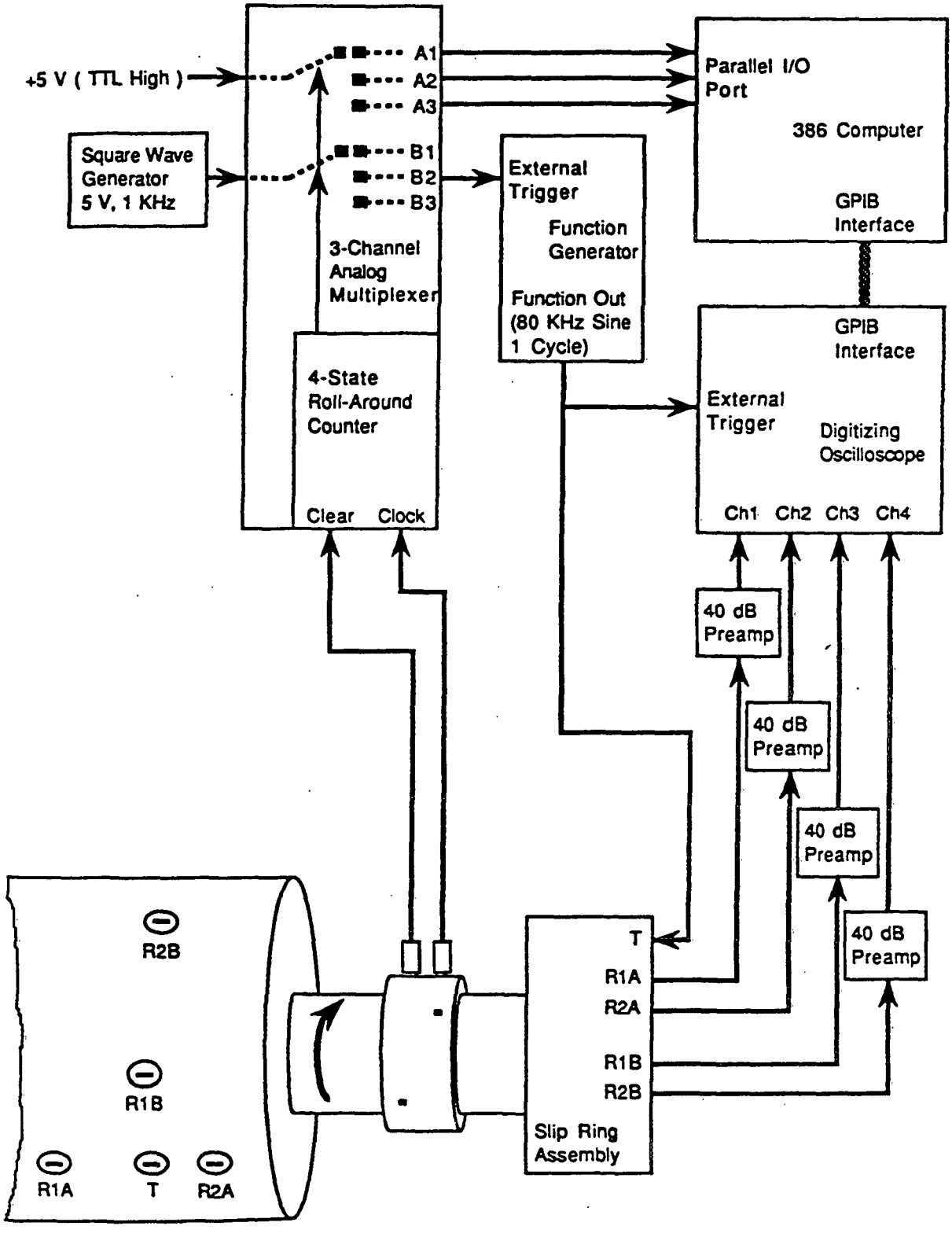


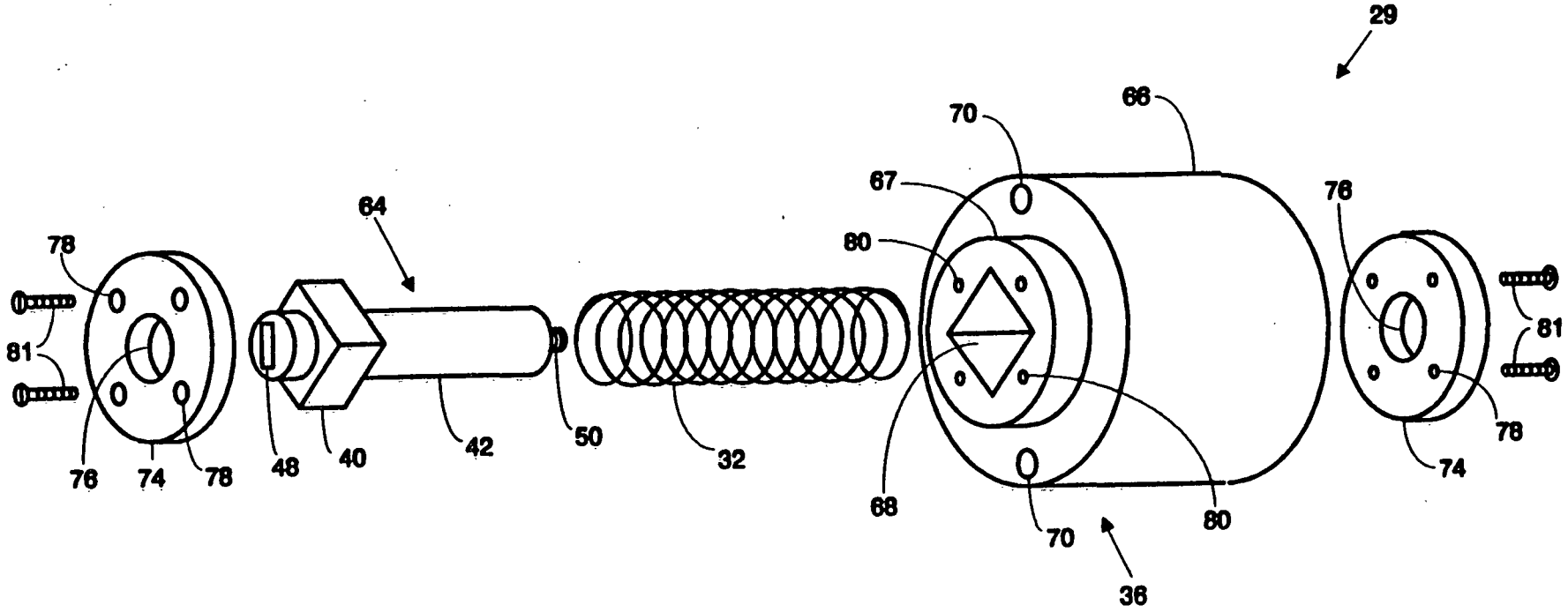
2_28_2.92 -> Foil-Start Avg 50 belt, 2000 f/m



ZD data. 42# Liner Belt at 2000 feet/minute. Thickness measured with MX caliper gauge.

In-Plane Ultrasonic Averaging Measurement System




29
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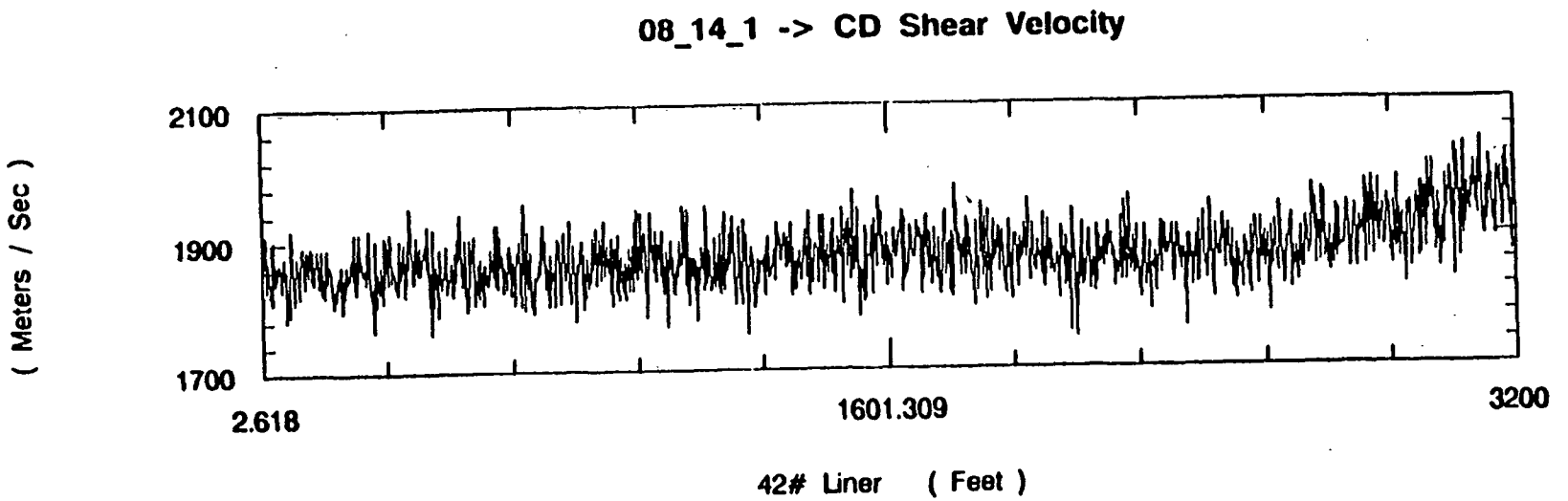
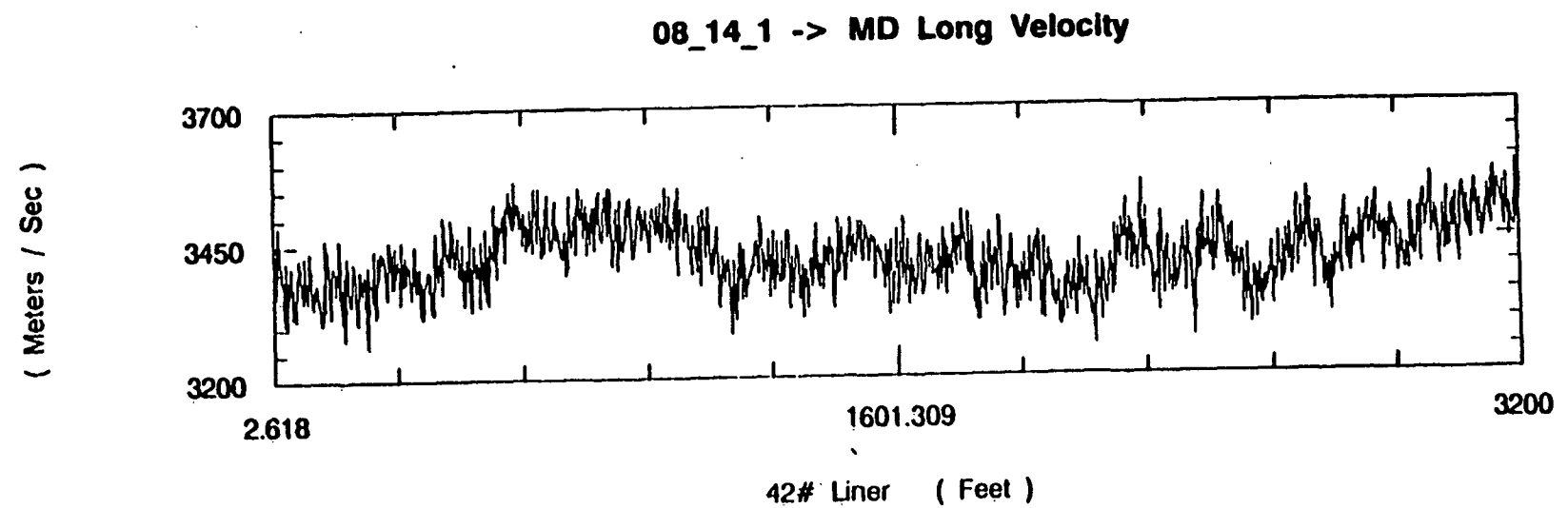
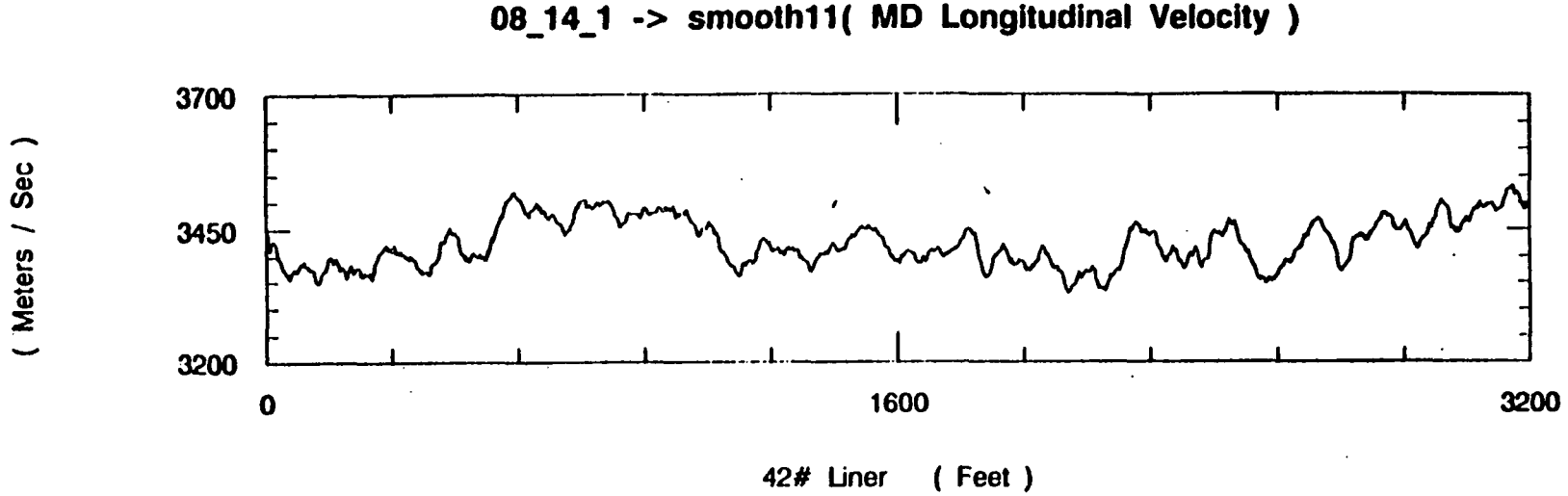
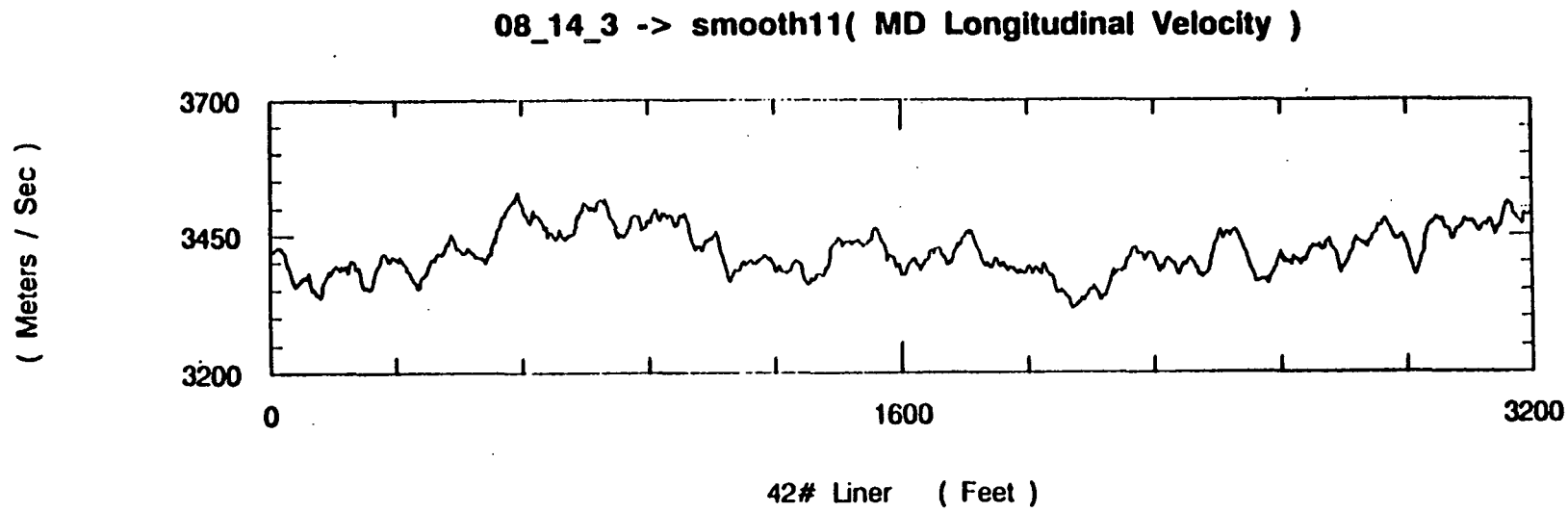
74
78
81



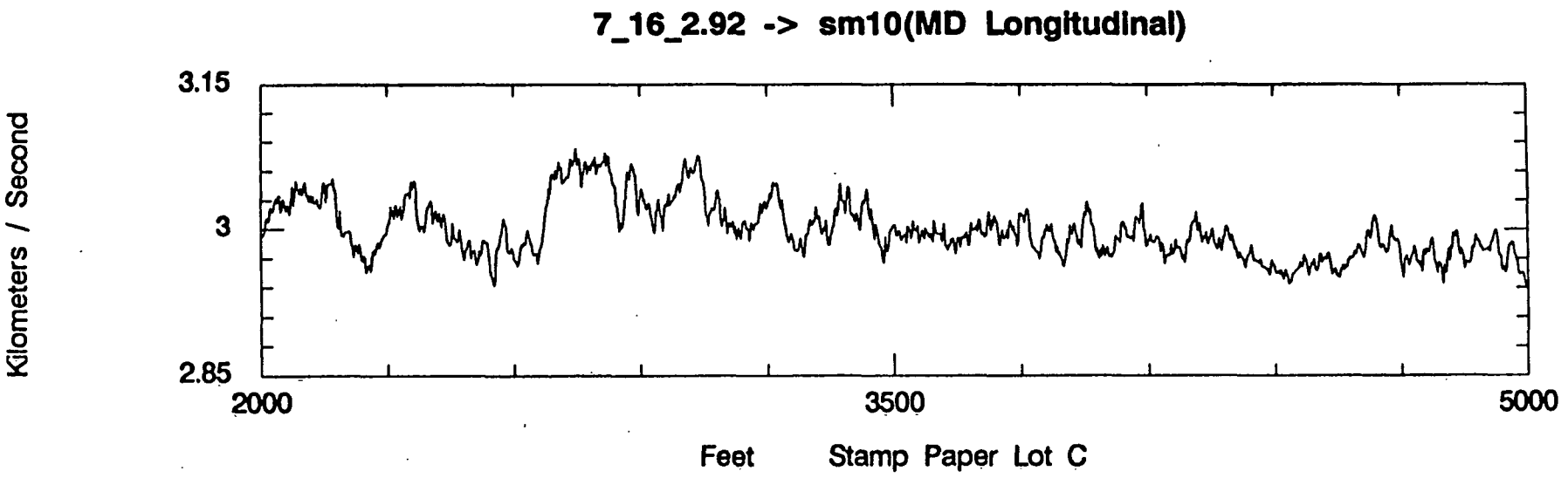


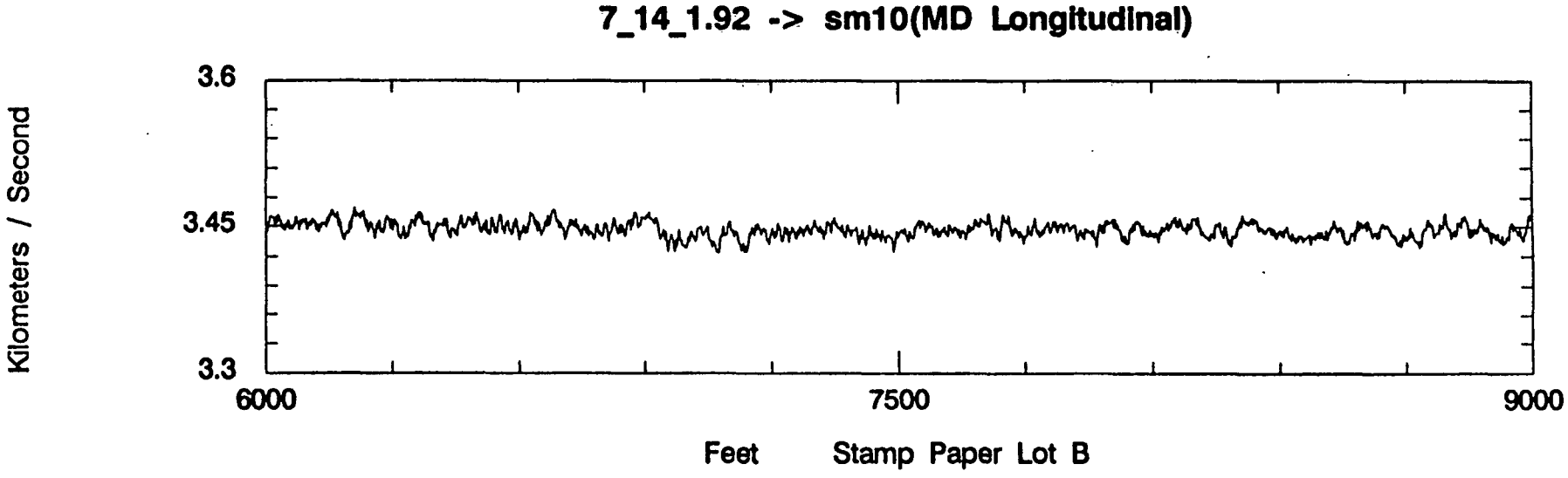
As collected in-plane data for CD Shear Velocity and MD Longitudinal Velocity for 3200 feet of 42# Liner.

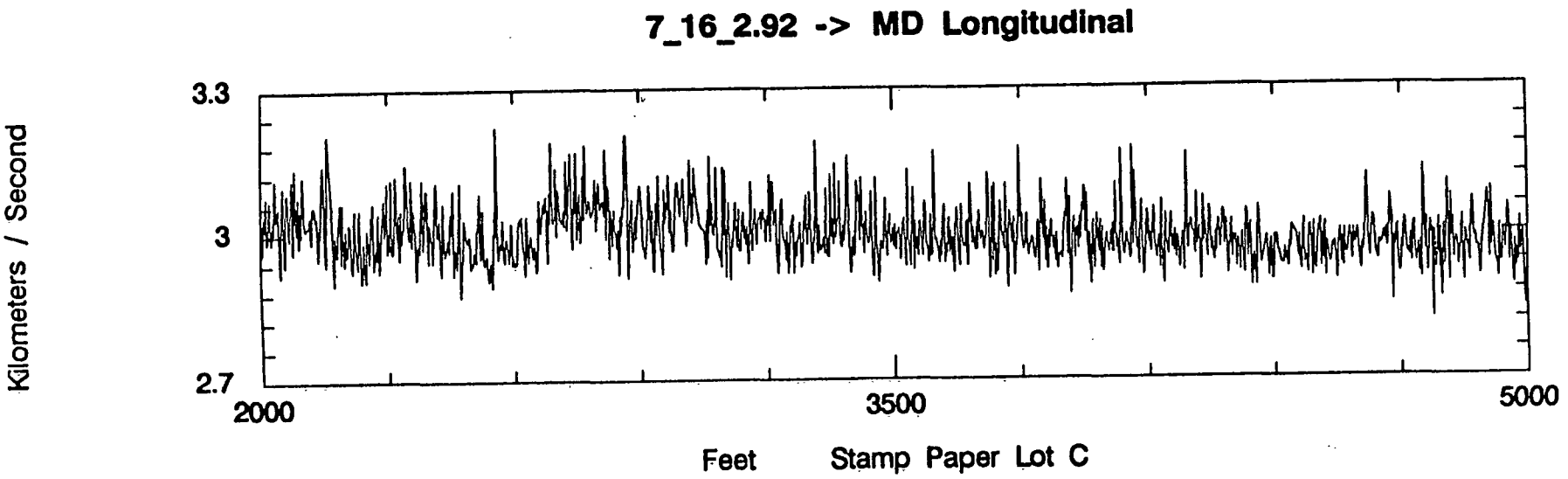


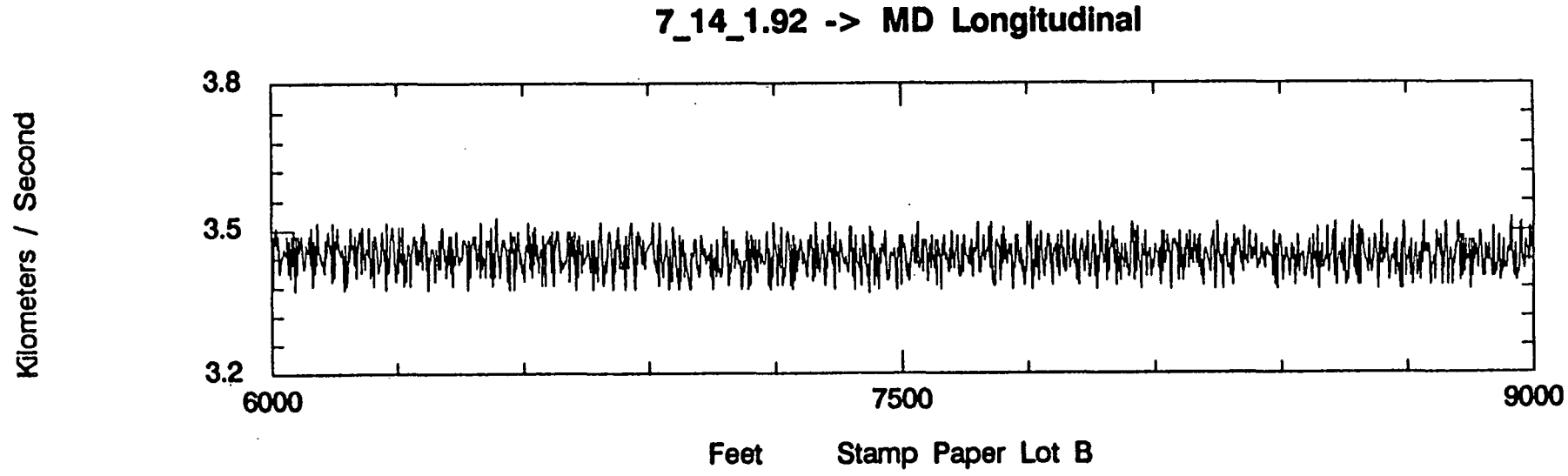


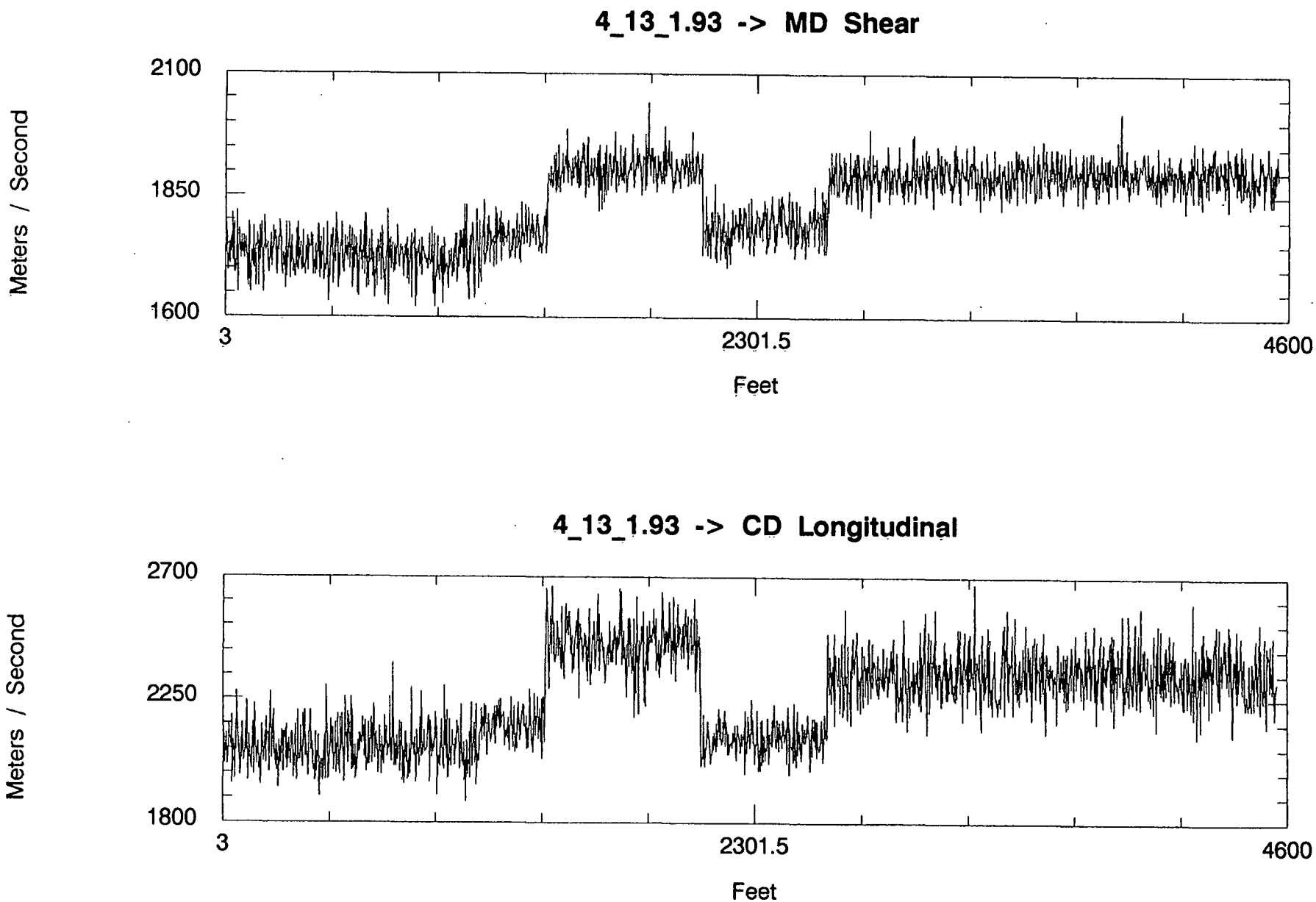
Smoothed in-plane data for MD Longitudinal Velocity
for repeated runs of 3200 feet of 42# Liner.

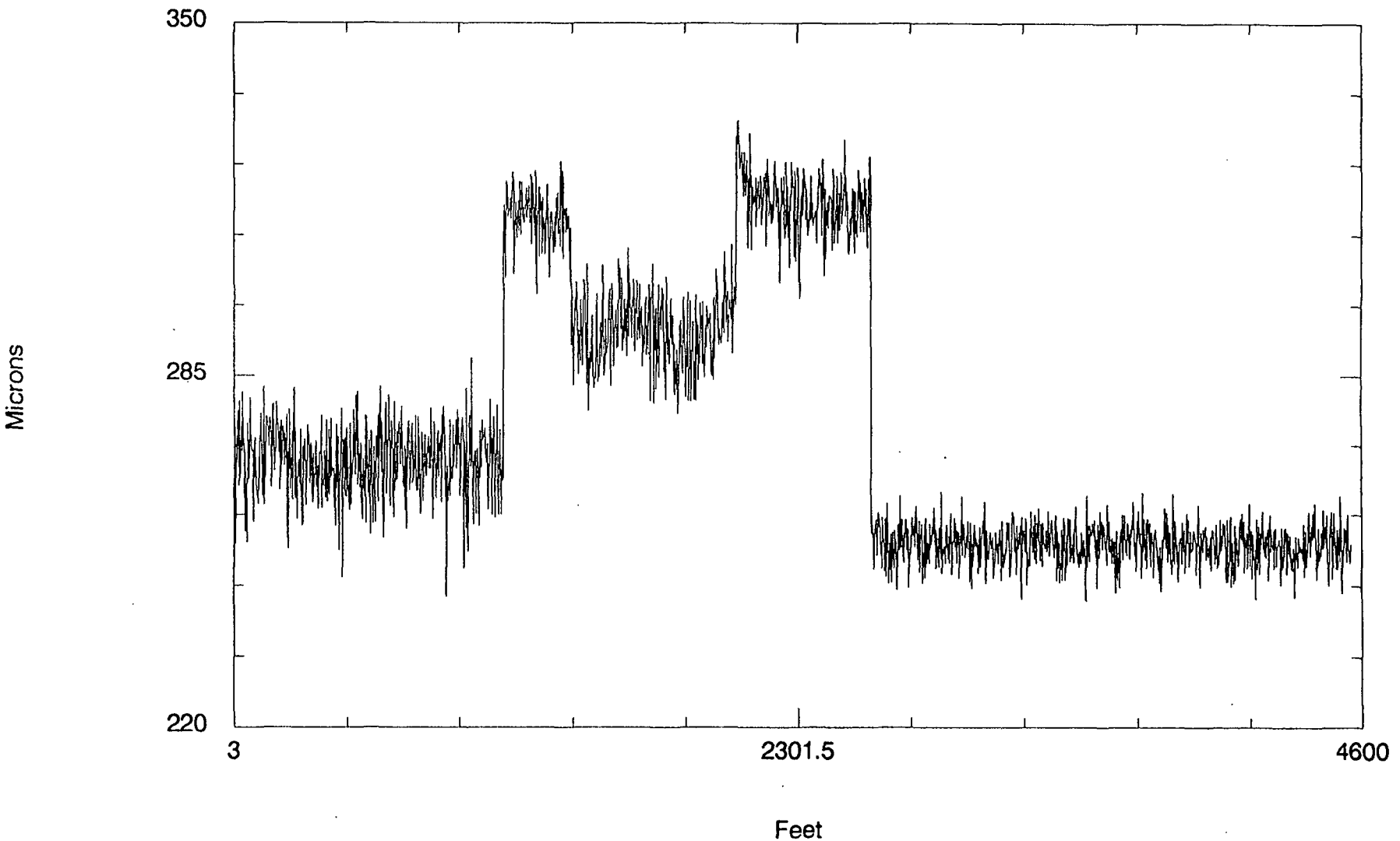

7_16_2.92 -> sm10(MD Longitudinal)
Kilometers / Second
3.15
3
2.85
2000
3500
5000
Feet
Stamp Paper Lot C

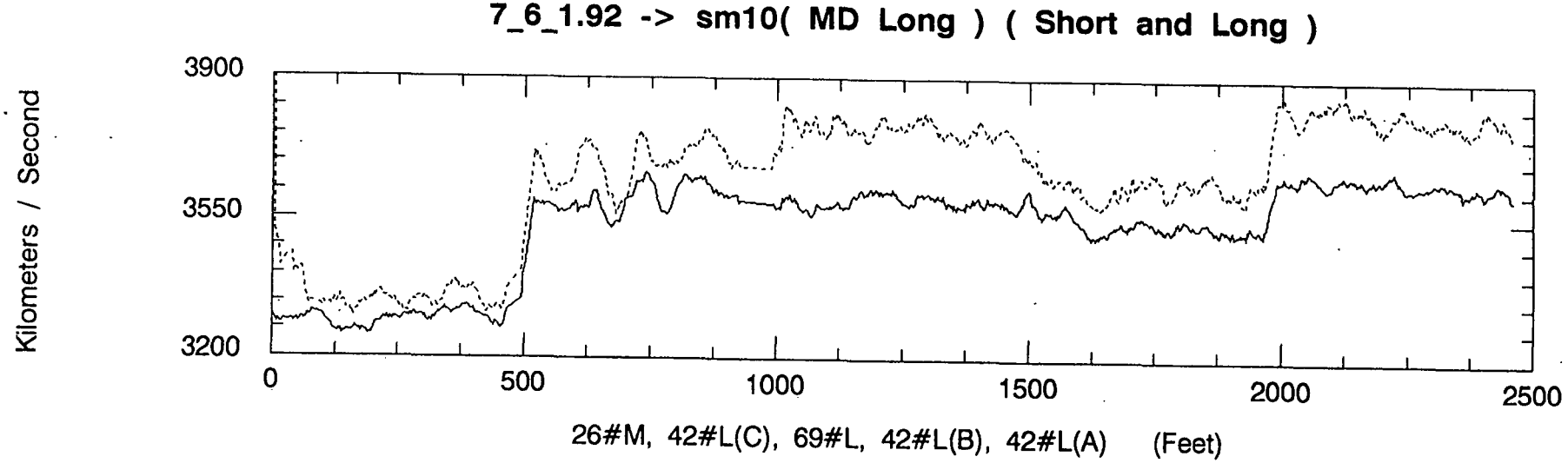

7_14_1.92 -> sm10(MD Longitudinal)
Kilometers / Second
3.6
3.45
3.3
6000
7500
9000
Feet
Stamp Paper Lot B

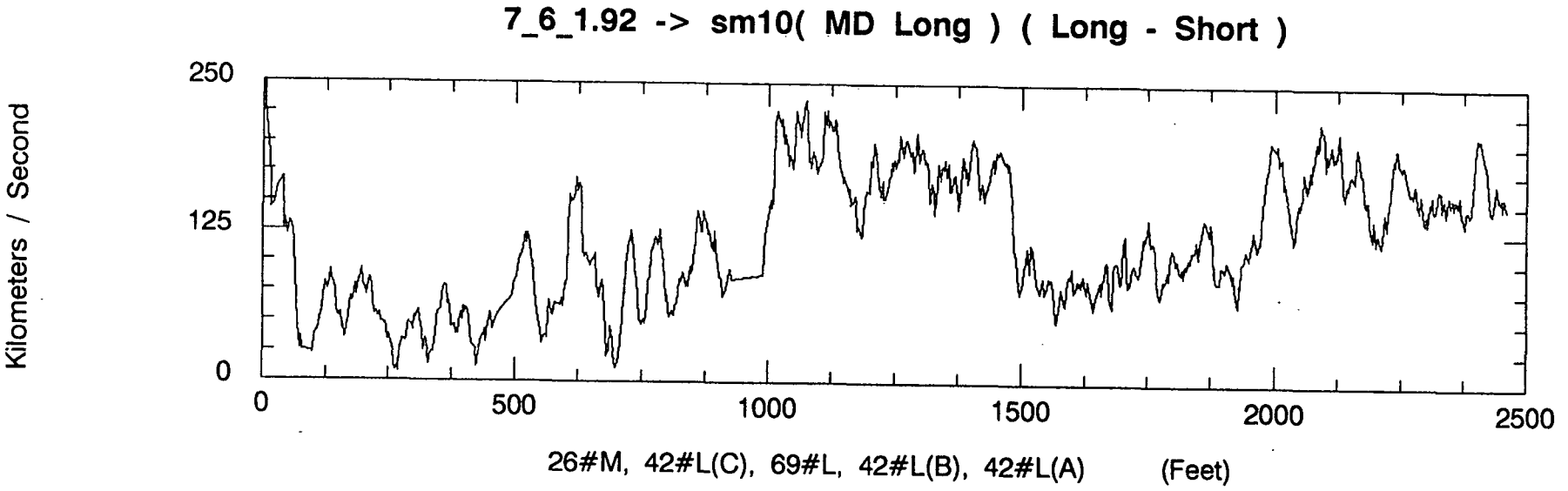

7_16_2.92 -> MD Longitudinal
Kilometers / Second
3.3
3
2.7
2000
3500
5000
Feet
Stamp Paper Lot C

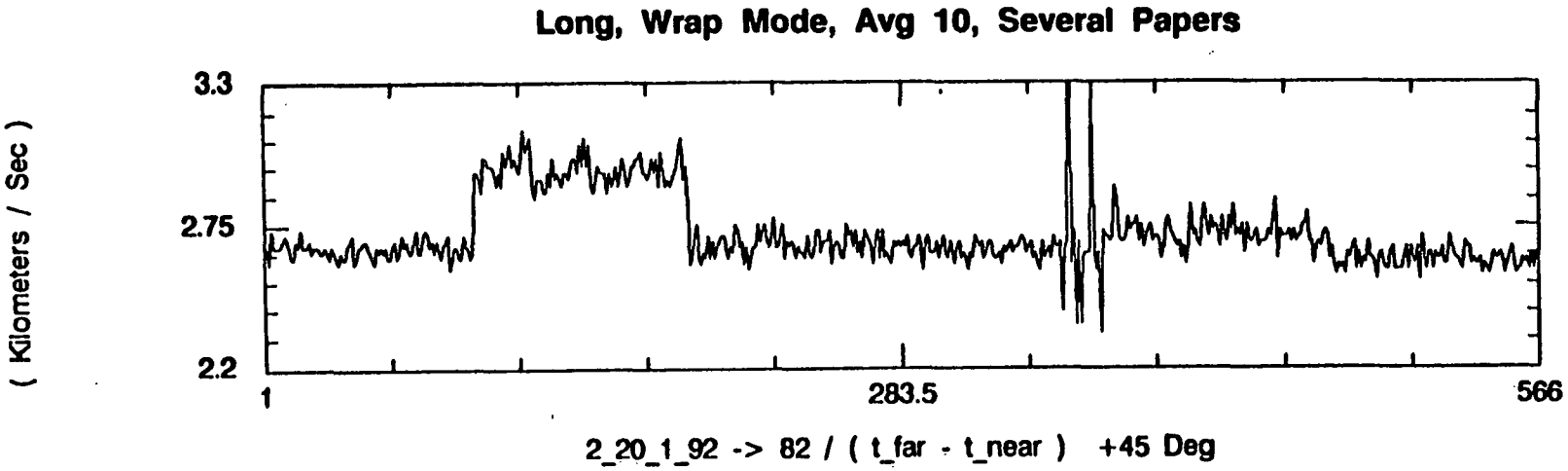

7_14_1.92 -> MD Longitudinal
Kilometers / Second
3.8
3.5
3.2
6000
7500
9000
Feet
Stamp Paper Lot B

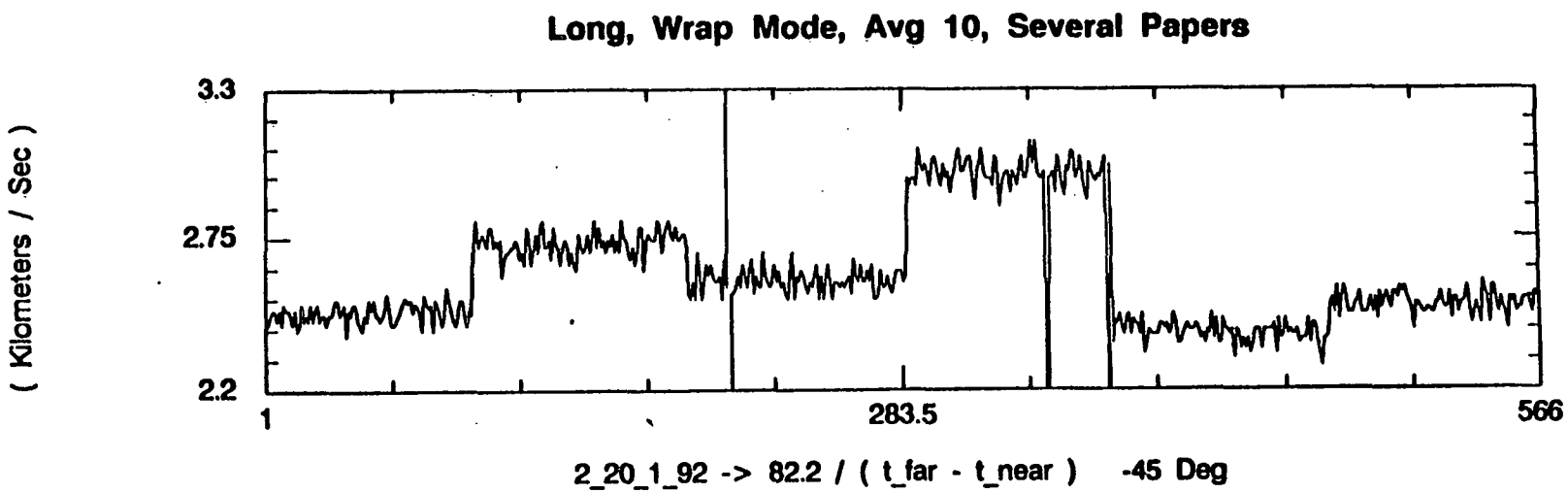

4_13_1.93 -> MD Shear
Meters / Second
2100
1850
1600
3
2301.5
4600
Feet
4_13_1.93 -> CD Longitudinal
Meters / Second
2700
2250
1800
3
2301.5
4600
Feet


4_13_1.93 -> MX Caliper
350
285
220
Microns
3
2301.5
4600
Feet


7_6_1.92 -> sm10(MD Long) (Short and Long)
Kilometers / Second
3900
3550
3200
0
500
1000
1500
2000
2500
26#M, 42#L(C), 69#L, 42#L(B), 42#L(A) (Feet)

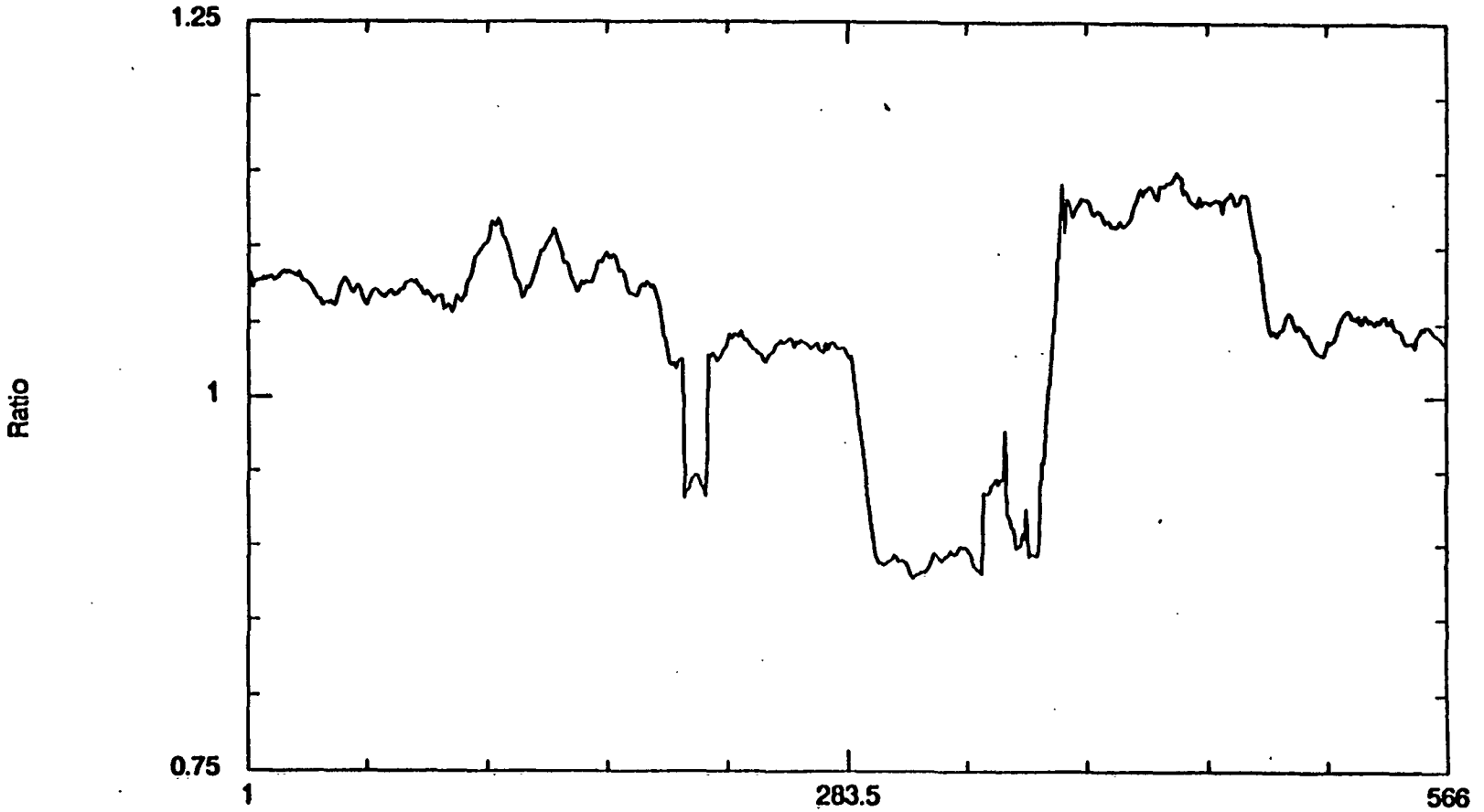

7_6_1.92 -> sm10(MD Long) (Long - Short)
Kilometers / Second
250
125
0
0
500
1000
1500
2000
2500
26#M, 42#L(C), 69#L, 42#L(B), 42#L(A) (Feet)





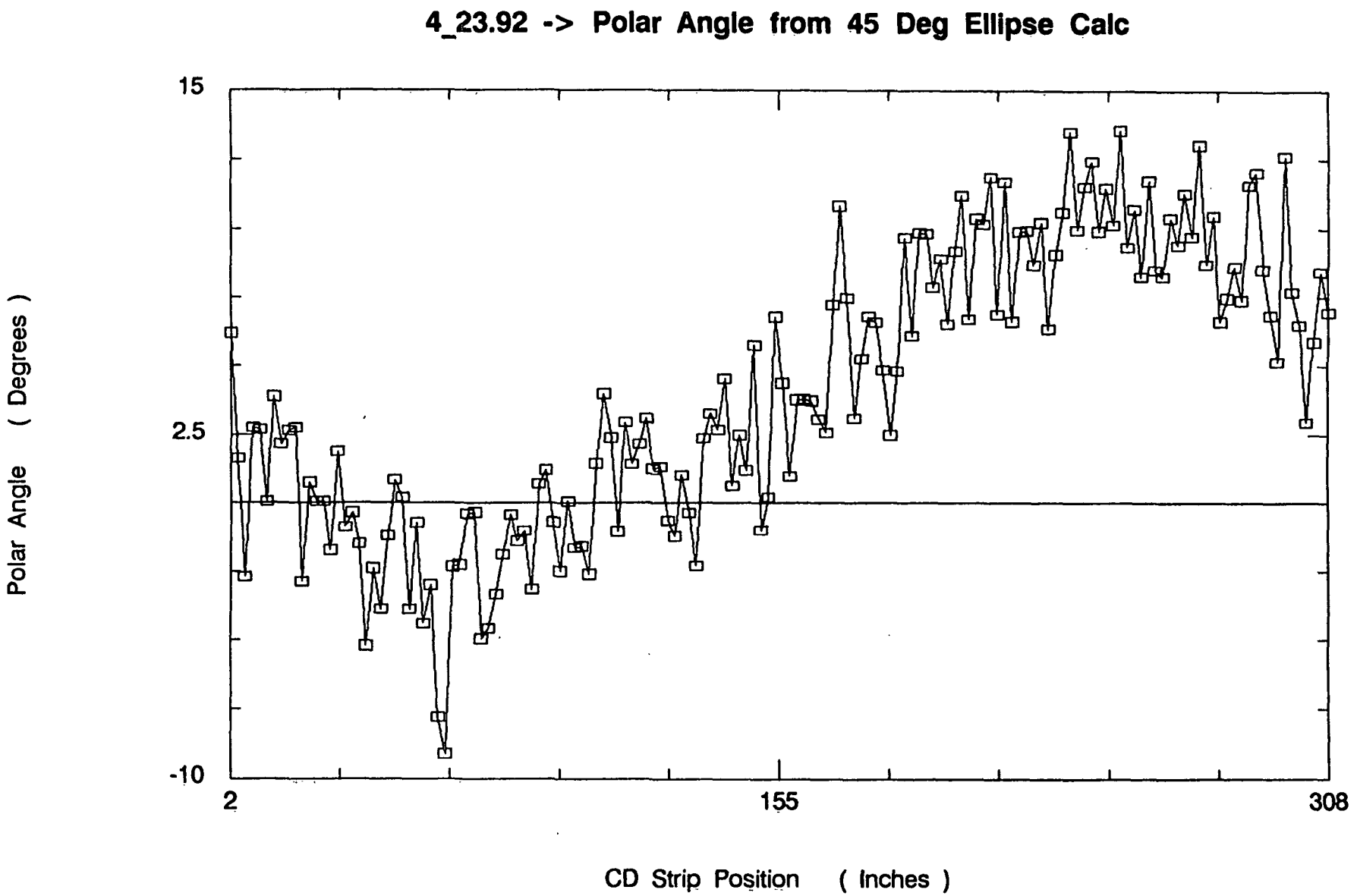
In-Plane data. Longitudinal velocity measured at +45 degrees to MD (top) and -45 degrees (bottom). Six section roll; 42# Liner(A), 42# Liner(B), 69# Liner, 42# Liner(C), 26# Medium, 42# Liner(A).

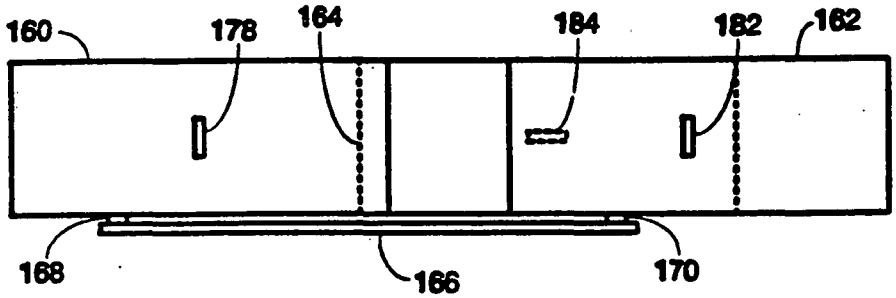
Longitudinal, Wrap Mode, Avg 10, Several Papers



2_20_1_92 -> smooth11((Vel +45) / (Vel -45))

In-plane data. Ratio of longitudinal velocities measured at plus and minus 45 degrees to MD for six section roll: 42# Liner(A), 42# Liner(B), 69# Liner, 42# Liner(C), 26# Medium, 42# Liner(A).


4_23.92 -> Polar Angle from 45 Deg Ellipse Calc
15
2.5
-10
2
155
308
Polar Angle (Degrees)
CD Strip Position (Inches)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166
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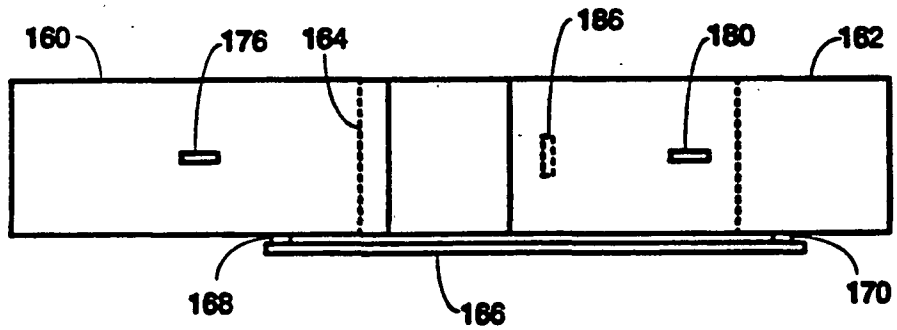
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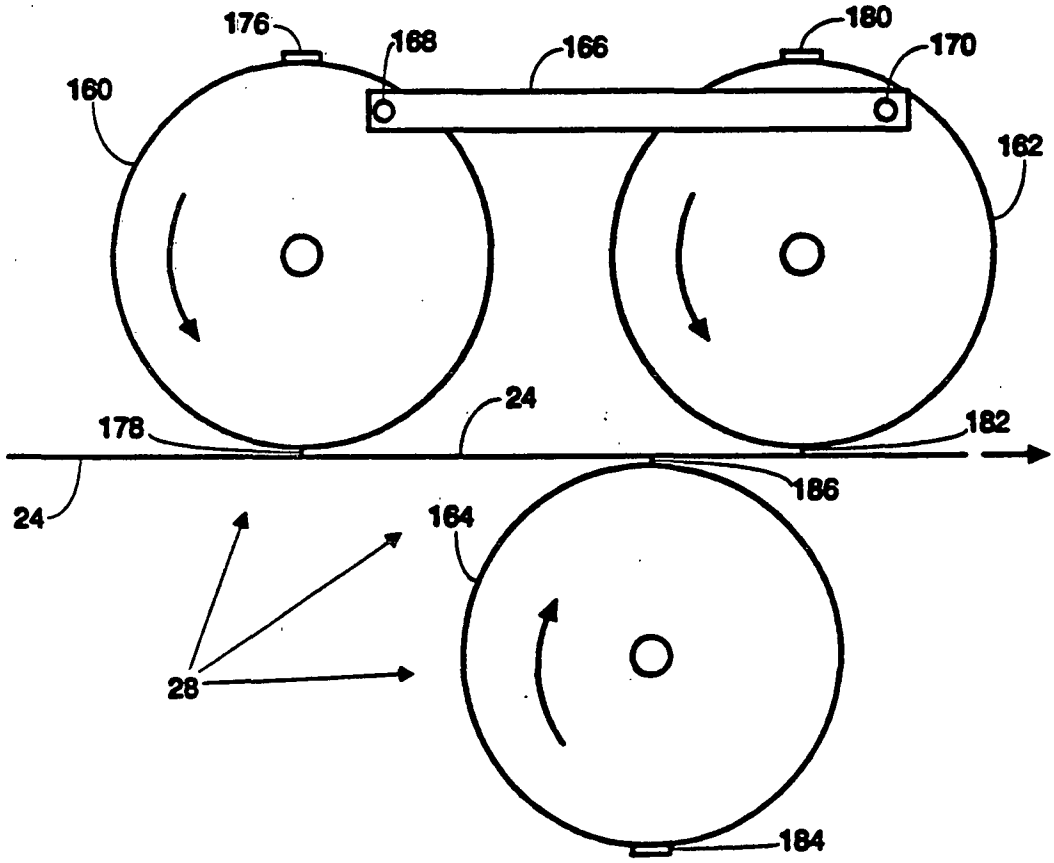
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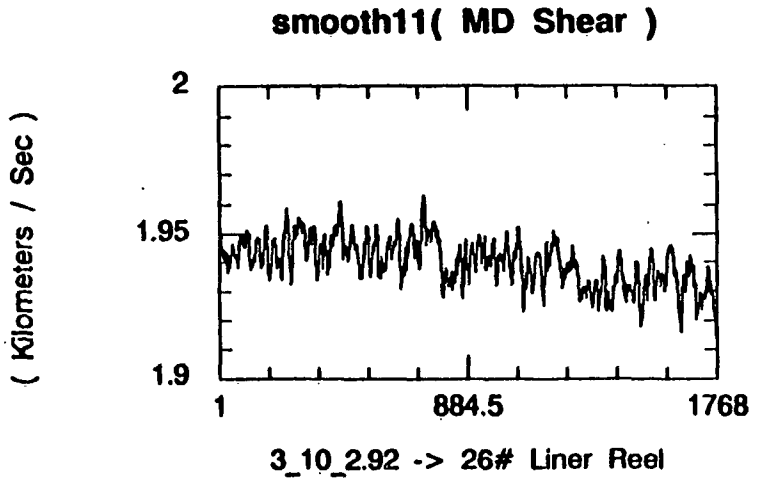
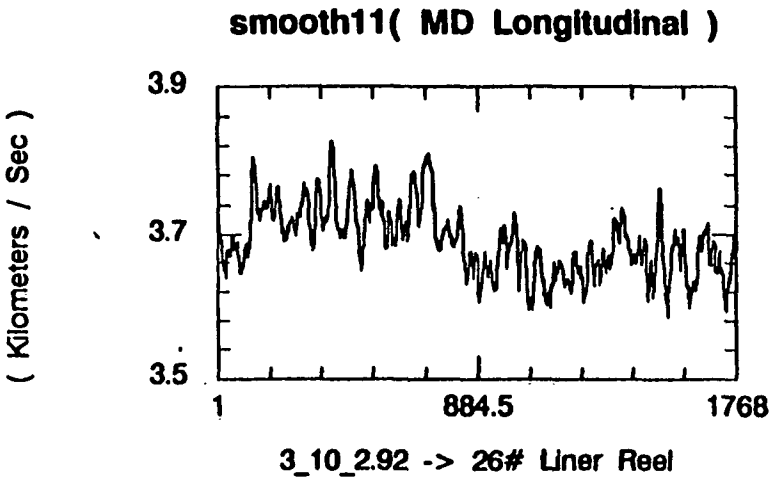
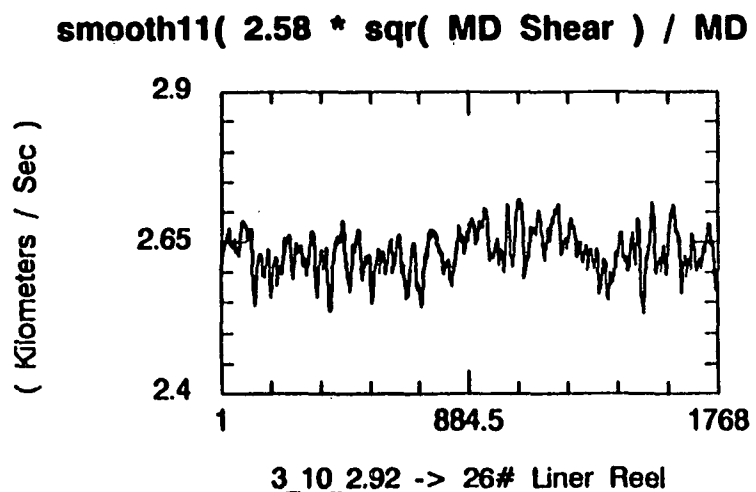
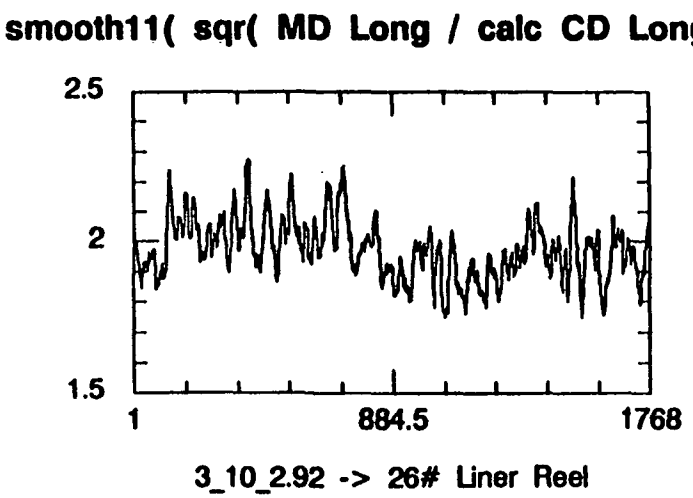
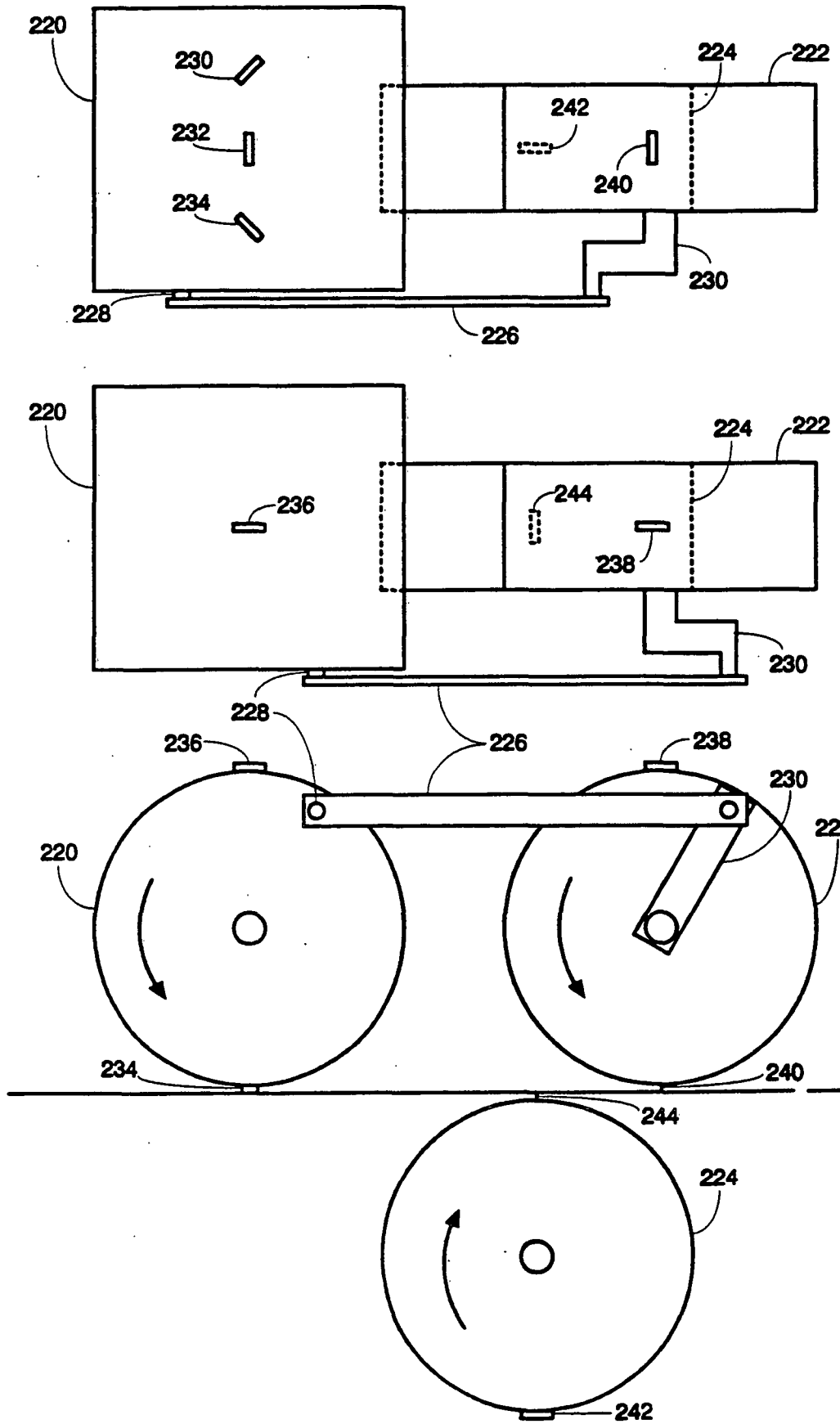








In-Plane data. Example of measurement with transducer sets aligned in the MD to measure MD Shear and MD Longitudinal velocities. CD Longitudinal and MD/CD stiffness ratio are calculated for 26# liner.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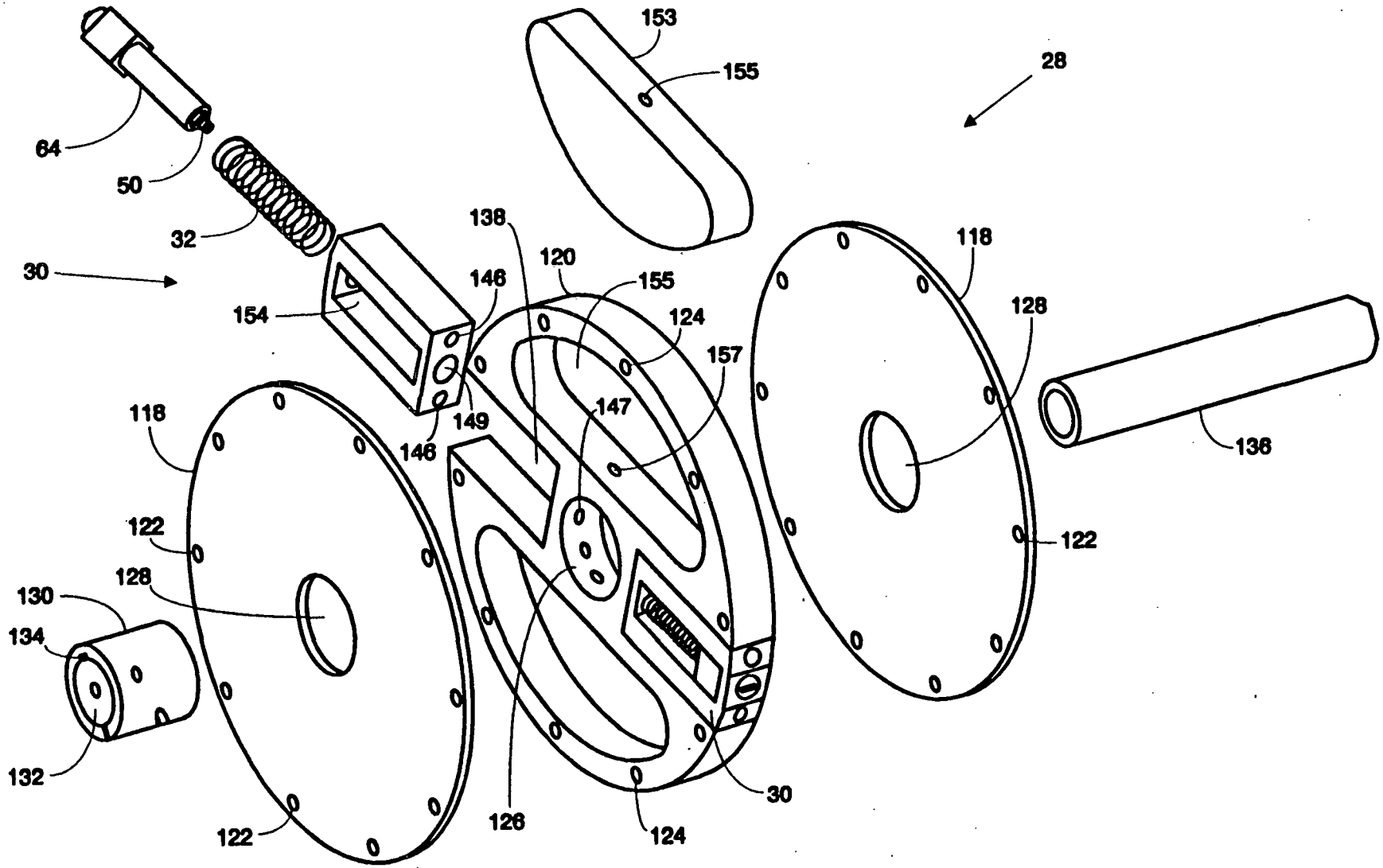
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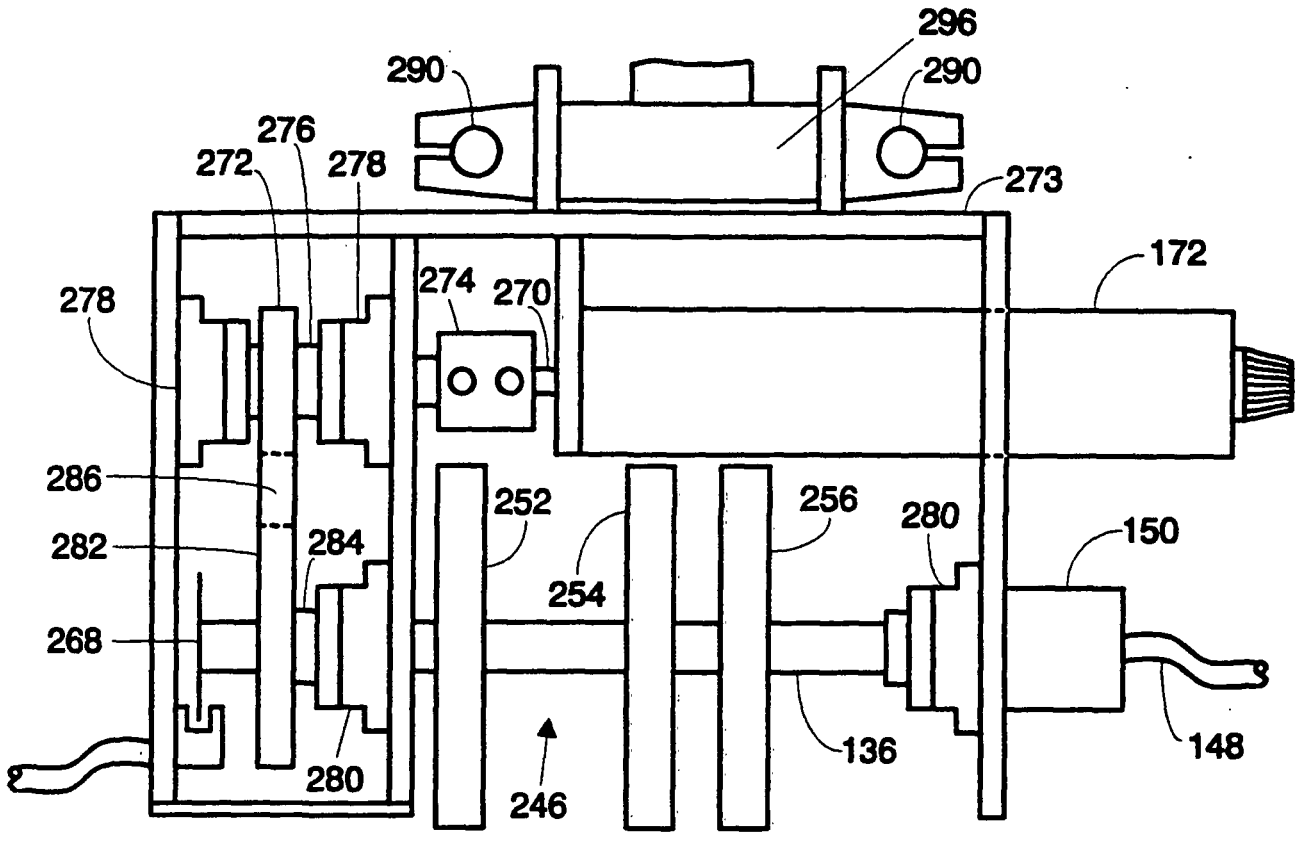
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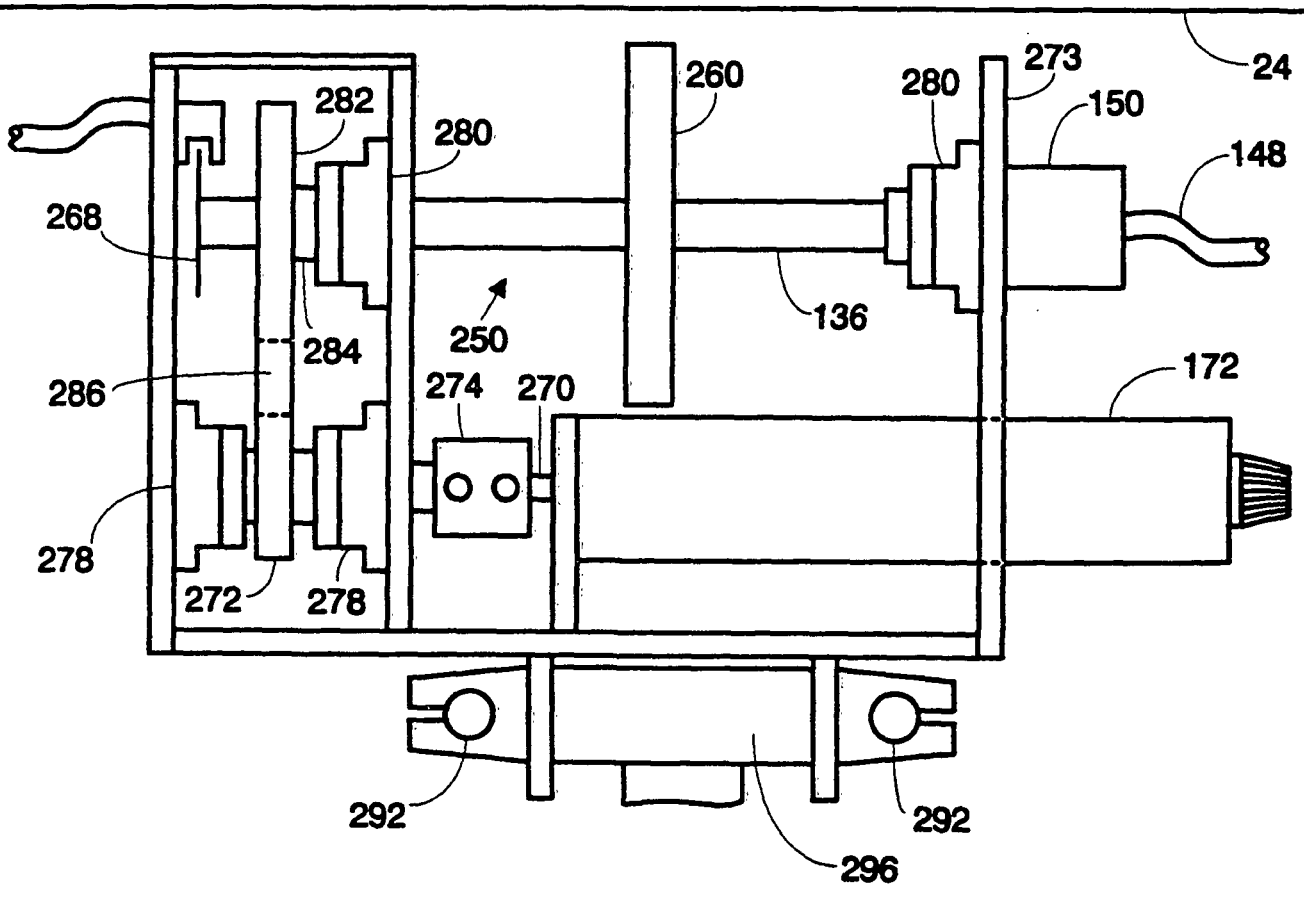
280
246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136
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286
274
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172
278
272
278
292
292
296

PAPER PHYSICS

FUNDAMENTALS OF ACOUSTIC RADIATION PRESSURE EFFECTS ON WET FIBERS

PROJECT 3767

April 29, 1993

Institute of Paper Science and Technology
Atlanta, Georgia

FUNDAMENTALS OF ACOUSTIC RADIATION PRESSURE EFFECTS

By

Pierre H. Brodeur
Associate Professor of Physics

FUNDAMENTALS OF ACOUSTIC RADIATION PRESSURE EFFECTS

PROJECT 3767

Pierre H. Brodeur

Paper Physics Group
Engineering and Paper Materials Division
Institute of Paper Science and Technology

April 29, 1993

- **PROJECT OBJECTIVES**
- **PRINCIPLES**
- **PROJECT STATUS**
- **APPLICATIONS**

PROJECT OBJECTIVES

1. To explain the translational and rotational motion of fluid suspended flexible and rigid fibers subjected to 1-D and 2-D plane standing wave fields in a quiescent fluid and in a Stokes flow;

PROJECT OBJECTIVES (Continued)

2. **To determine the conditions promoting acoustic reorientation at the expense of acoustic migration and vice-versa;**

PROJECT OBJECTIVES (Continued)

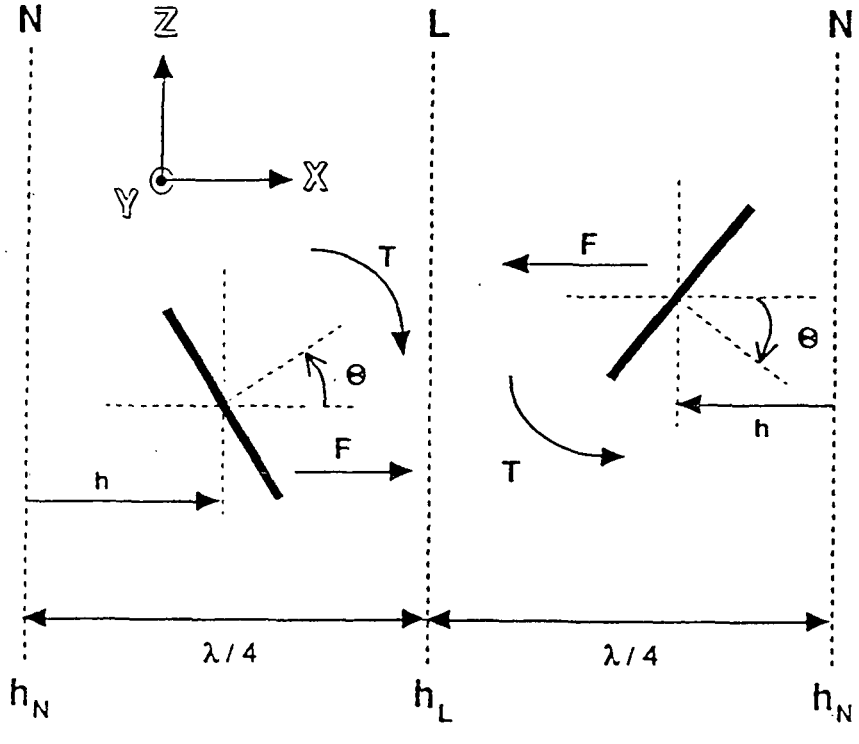
3. To demonstrate the hypothesis that the acoustic radiation force can be used to evaluate wet fiber flexibility.

PRINCIPLES

- **Consider a pulp slurry interacting with a 1-D plane standing wave ultrasonic field produced by an acoustic resonator**

- **Simplification: fibers = rigid cylinders**

Rigid Cylinders subjected to Acoustic Radiation Force and Torque in a 1-D Plane Standing Wave Field



ACOUSTIC RADIATION FORCE:

$$F_{SW} = f(\beta)\frac{\pi a^2}{2}\bar{E}\sin[2kh]$$

$$f(\beta) = [2(1-\beta)/(1+\beta)+1] \quad , \quad \beta = \frac{\rho_{fluid}}{\rho_{fiber}}$$

EFFECTS:

- **Migration**
- **Agglomeration**
- **Layering**
- **Separation**

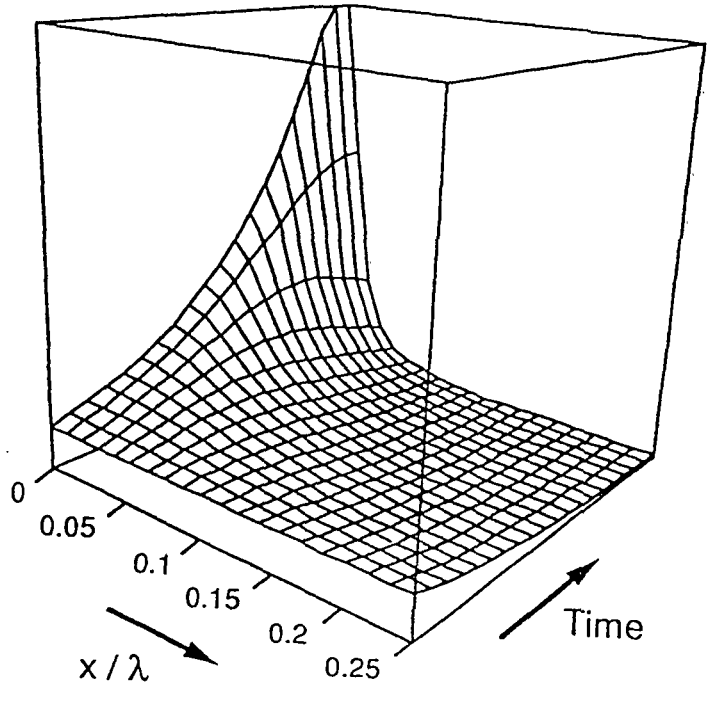
ACOUSTIC RADIATION TORQUE:

$$T_{SW} \propto -(\pi a^2 l)\,\bar{E}\sin[2\theta]\sin^2[k\,h]$$

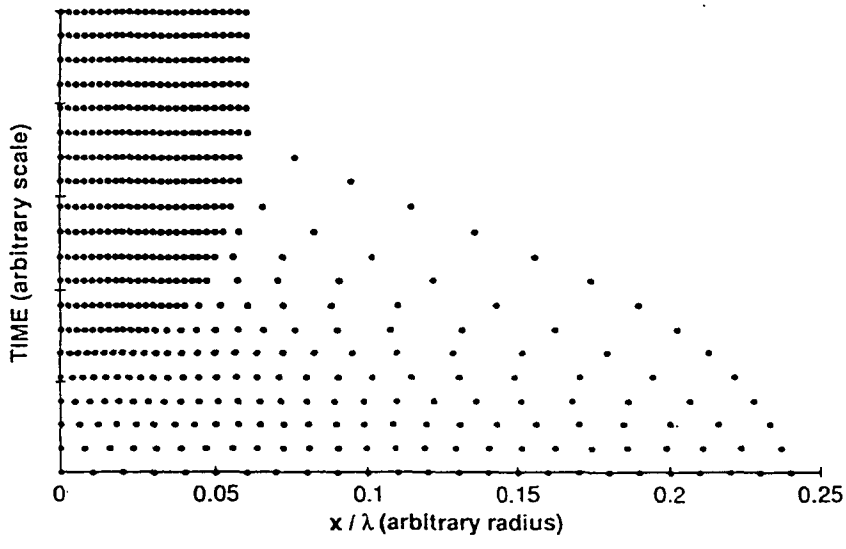
EFFECTS:

- **Reorientation**
- **Alignment**

Continuous Distribution of Cylinders as a Function of Time



Cylinder Trajectories for a Discrete and Homogeneous Distribution at time = 0



PROJECT STATUS

1. Acoustic resonator development

2. Experimental setup development

DEVELOPMENT OF RESONATORS

- **Phase I: Design of resonator and test-stand assembly (completed in September 1992)**
- **Phase II: Construction of first resonator and test-stand assembly (completed in January 1993**
- **Phase III: Construction of additional resonators + integral hydrophones (late 1993)**

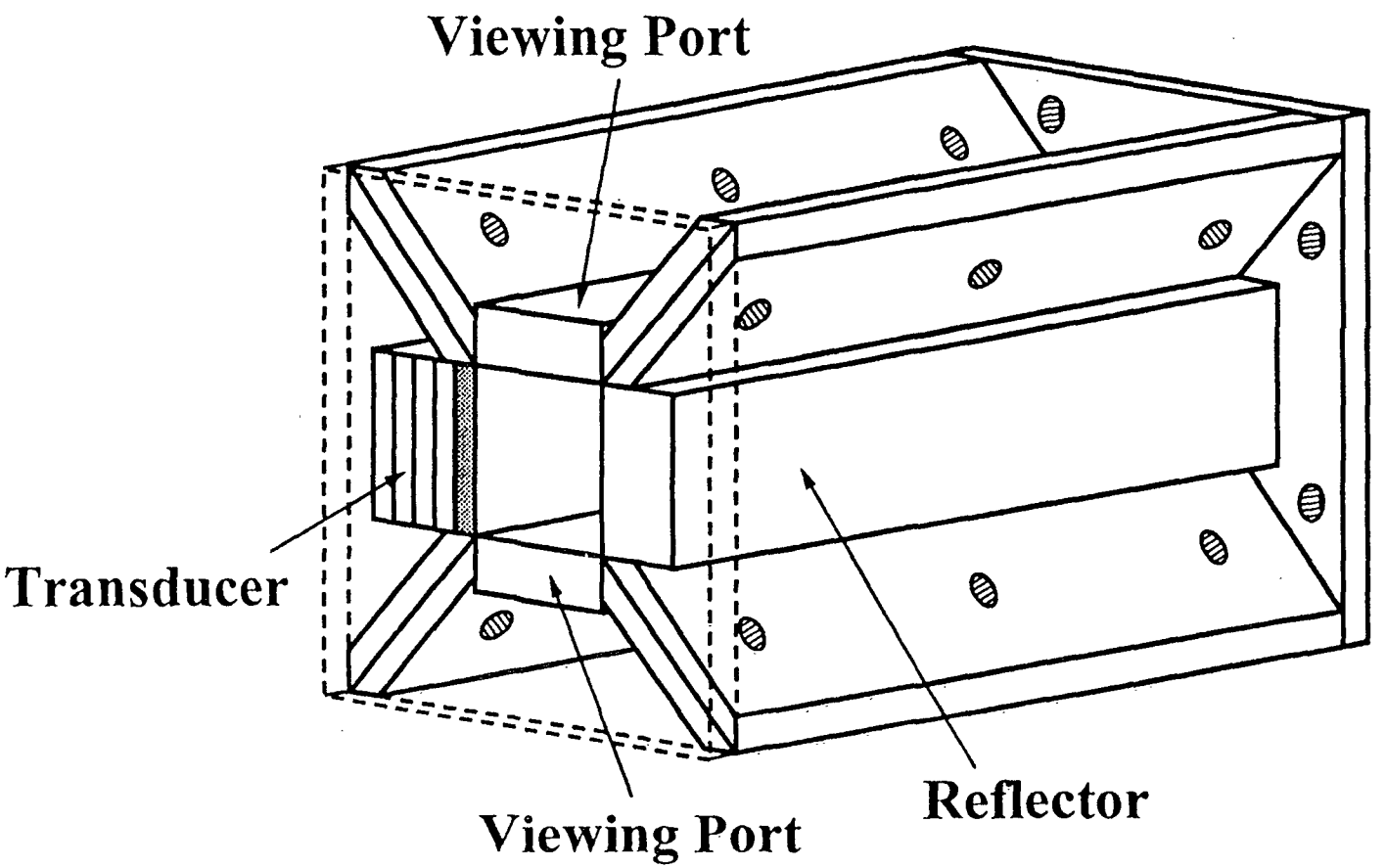
RESONATOR SPECIFICATIONS

- Modular design
- Four-layer piezoelectric ceramic transducer + graphite matching layer
- Stainless steel reflector
- Lateral viewing ports

RESONATOR SPECIFICATIONS (continued)

- **Resonance length: 2 cm**
- **Transducer width: 2 cm**
- **Transducer length: 10 cm**
- **Frequency: 150 kHz**
- **Wavelength: 1 cm in water**

ONE-DIMENSIONAL ACOUSTIC RESONATOR



EXPERIMENTAL INVESTIGATION

- **Acoustic Parameters:**
    - **1-D and 2-D plane standing wave fields**
    - **Acoustic wavelength**
    - **Acoustic power**
    - **Acoustic dwell length**

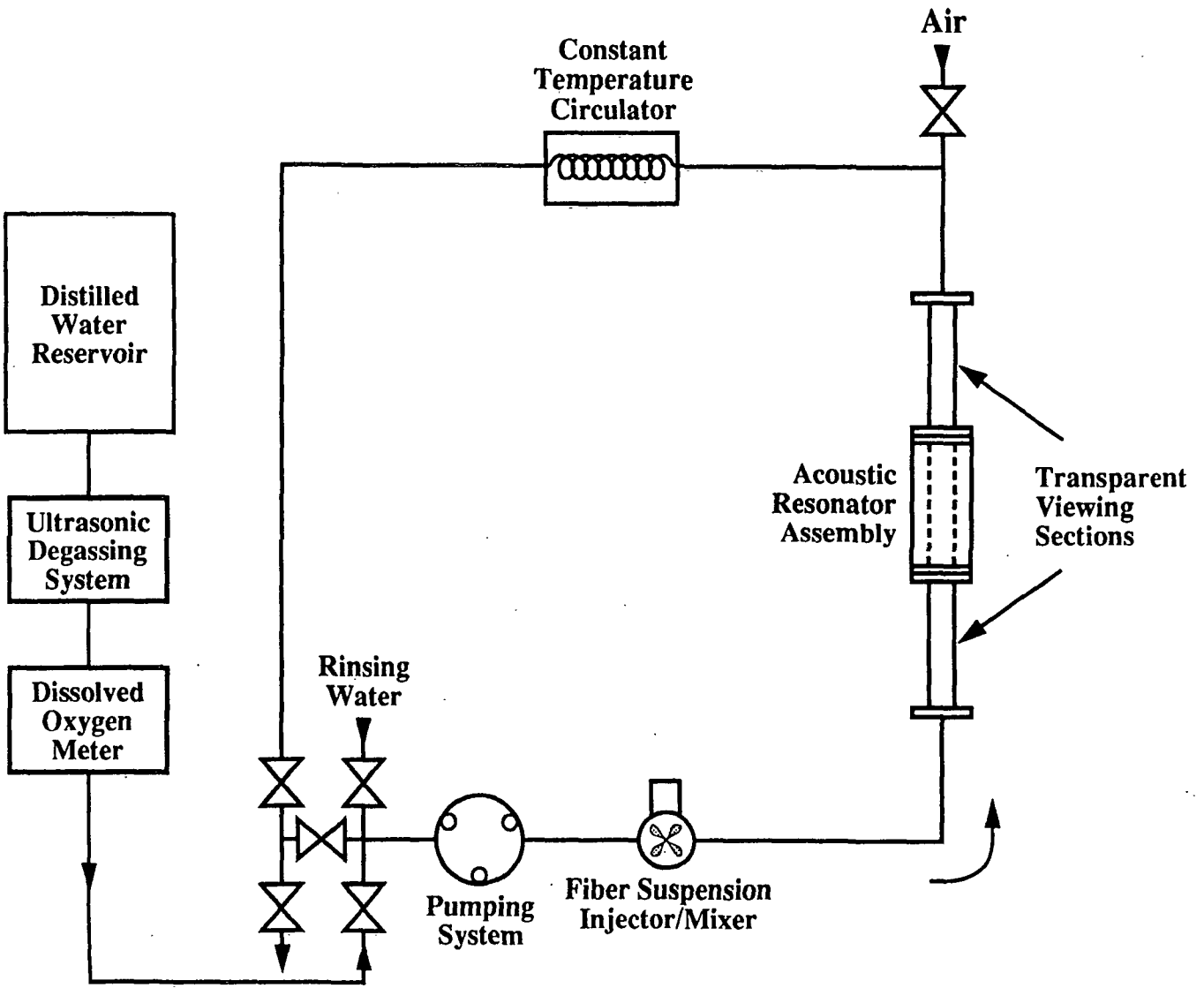
EXPERIMENTAL INVESTIGATION (cont'd)

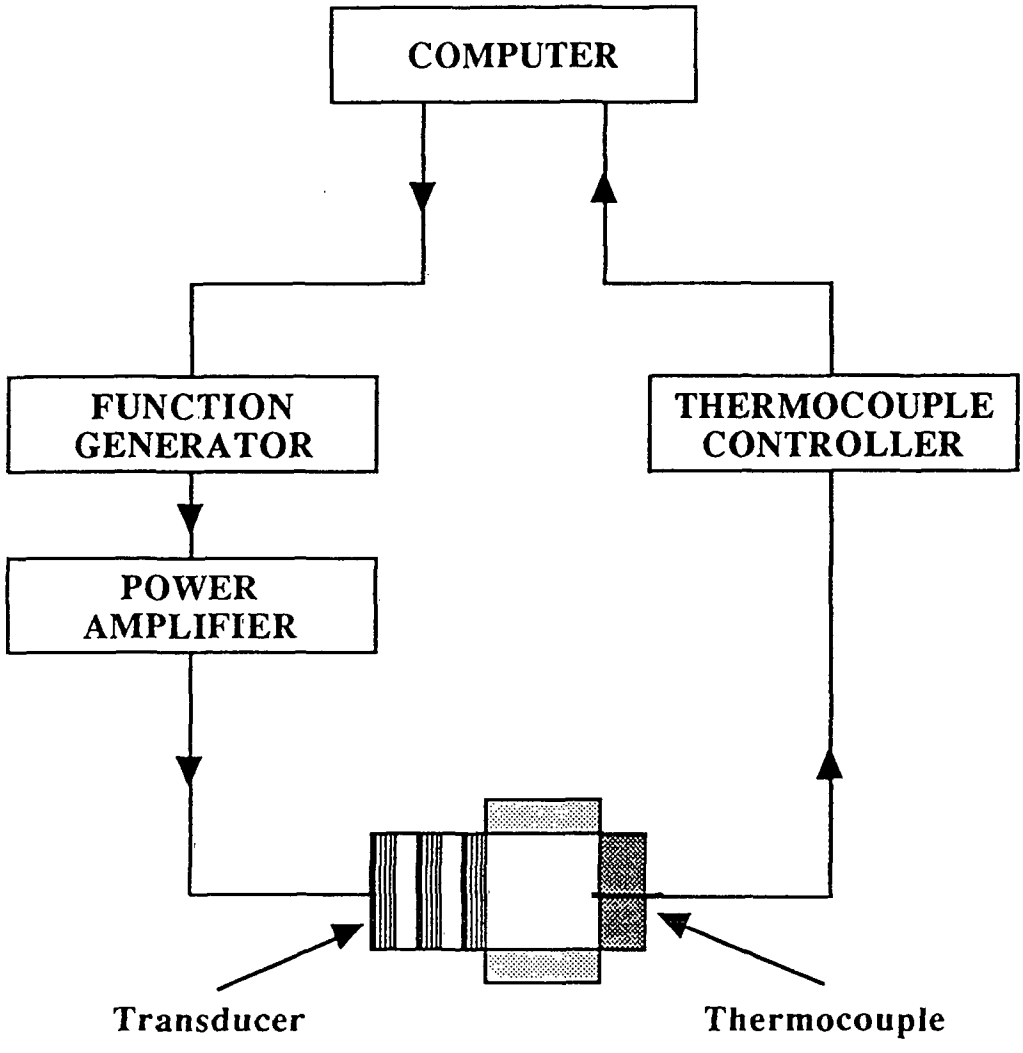
- **Suspending Medium Parameters:**
  - **Degassed water**
  - **Quiescent fluid and Stokes flow conditions**
  - **Temperature effects**
  - **Gravitational effects**

EXPERIMENTAL INVESTIGATION (cont'd)

- **Fiber Suspension Parameters:**
  - **Aspect ratio (radius/length)**
  - **Density**
  - **Flexibility**
  - **Consistency**
  - **Rayon fibers**
  - **Kraft and TMP pulp fibers**

Schematic of the Flow Loop System



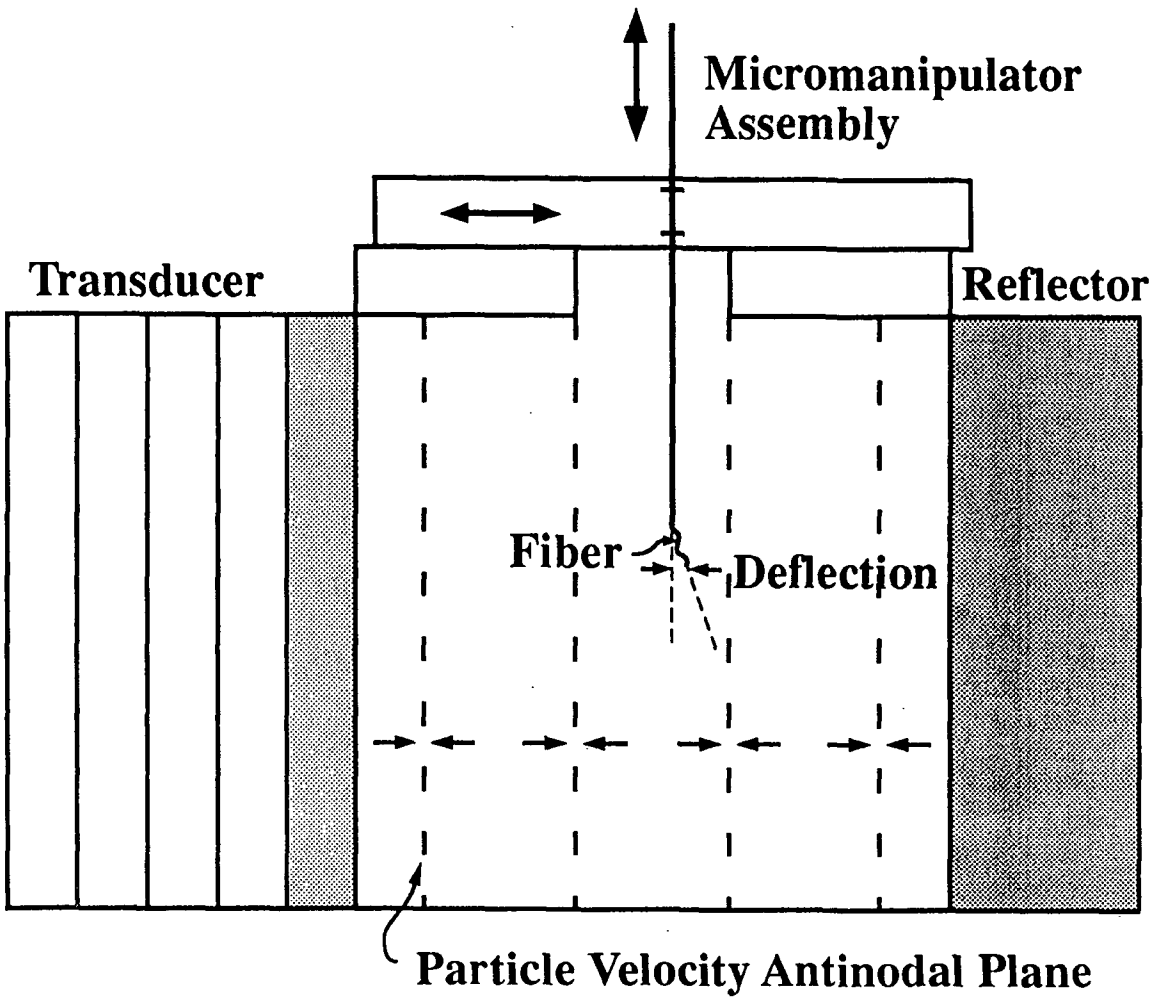


TEMPERATURE COMPENSATION SYSTEM

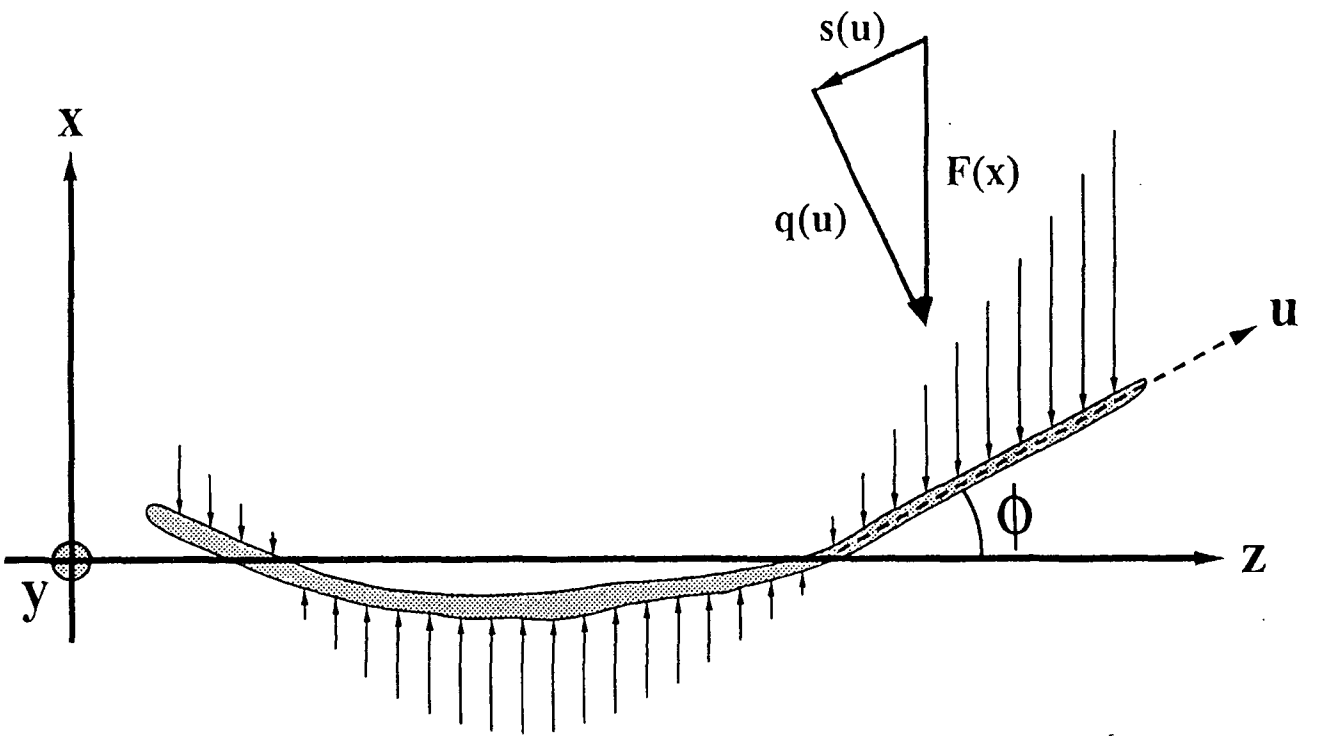
EXPERIMENTAL INVESTIGATION (cont'd)

- **Wet fiber flexibility research program:**
  - **Phase I: Acoustic bending of a fluid suspended fiber attached to a micromanipulator;**
  - **Phase II: Acoustic bending of fluid suspended fibers stabilized by a 2-D plane standing wave field;**
  - **Phase III: Acoustic bending of fluid suspended fibers penetrating a standing wave field.**

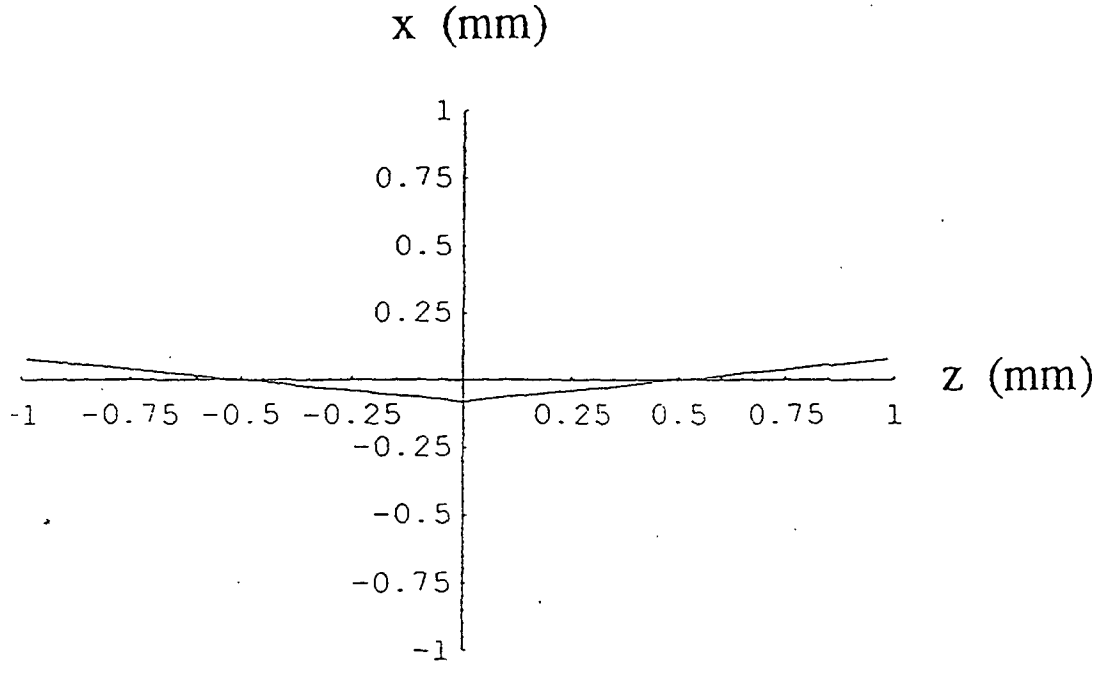
Schematic of Fiber Deflected by Acoustic Radiation Force



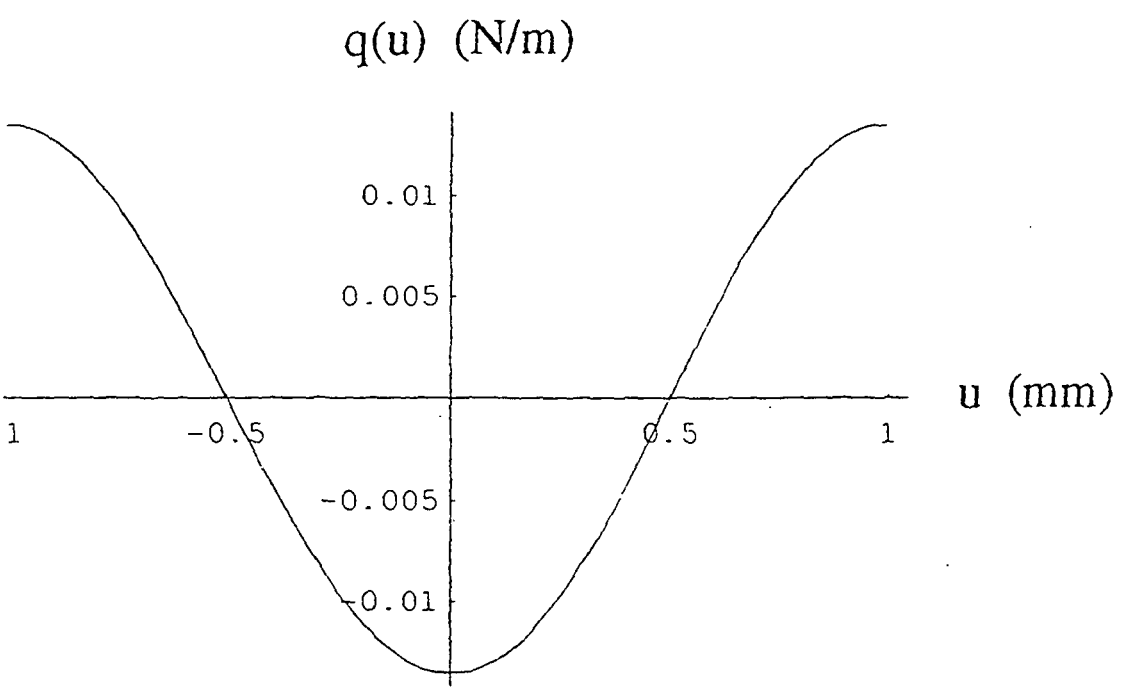
SINGLE FIBER SUBJECTED TO A DISTRIBUTED ACOUSTIC LOAD



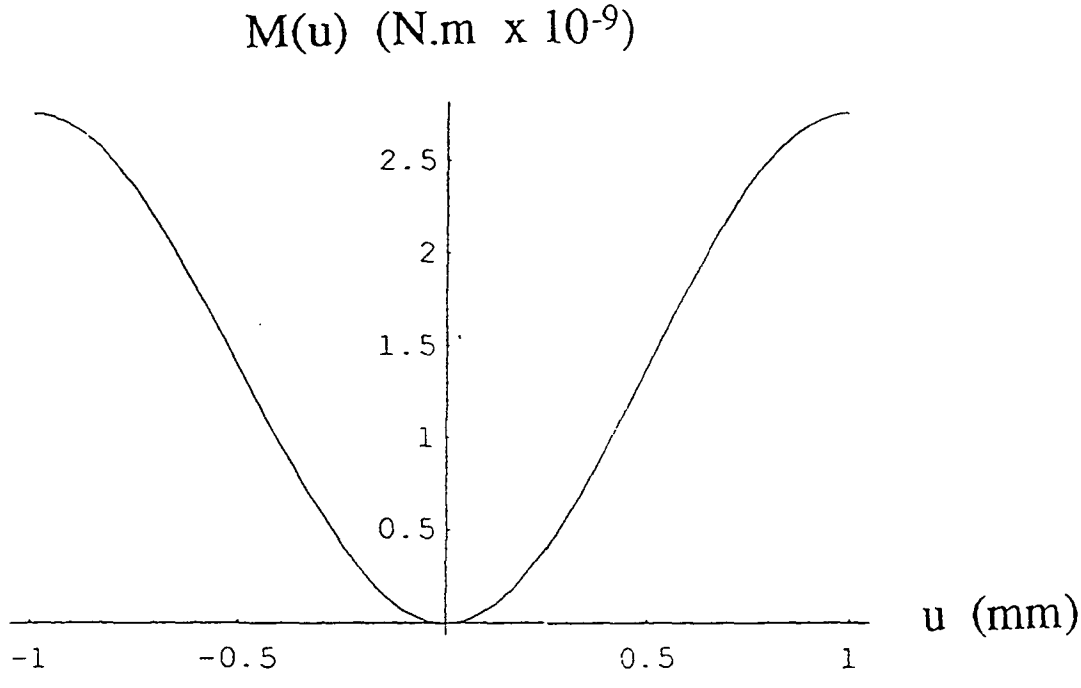
Stabilized Fiber in a 1-D Plane Standing Wave Field (Sound Field Reference Frame)



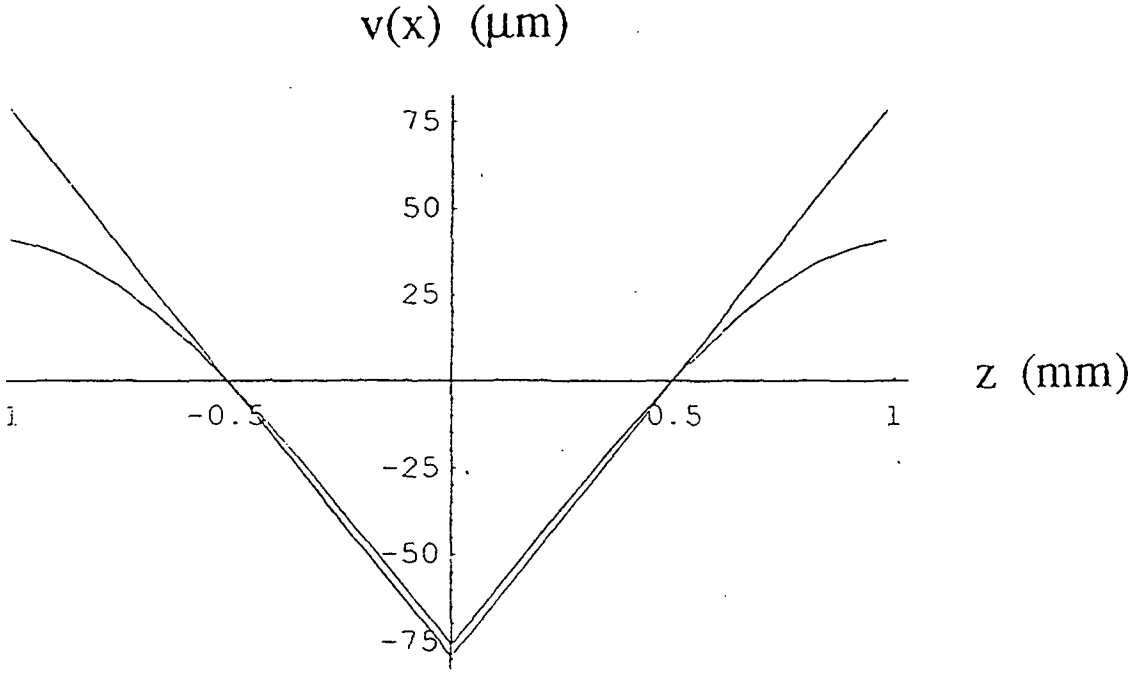
Normal Acoustic Load Acting on the Fiber (Fiber Reference Frame)



Induced Bending Moment (Fiber Reference Frame)



Fiber Lateral Deflection (Sound Field Reference Frame)



OTHER APPLICATIONS

- **Fiber compactibility/conformability analysis**
- **Monitoring of average fiber length**
- **Acoustic fiber orientation control**

OTHER APPLICATIONS (cont'd)

- **Acoustic fiber-particle separation processes**
- **Acoustic rearrangement of a dilute fiber suspension**
- **Acoustic forming of single layer / multilayer paper and board materials**